Fire and Life Safety Analysis
Building V

Andrew Ko

FPE 596 – Culminating Experience in Fire Protection Engineering

Spring 2019

California Polytech University

San Luis Obispo

Statement of Disclaimer
This project report is a result of a class assignment; it has been graded and accepted as fulfillment of the course requirements. Acceptance of this report in fulfillment of the course requirements does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include, but may not be limited to, catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

Keywords:

Performance Based Design

ASET

RSET

Fire Model

FDS

EXECUTIVE SUMMARY

A fire and life safety analysis was completed for Building V as part of a culminating project in the California Polytech University at San Luis Obispo Fire Protection Engineering Master's Degree Program. This report will detail both a prescriptive design based on the 2013 California Building Code and applicable standards as well as a performance based analysis based on a design fire scenario.

The prescriptive design will discuss four main components of compliance:

- Structural Fire Protection
- Fire Alarm
- Fire Sprinkler
- Means of Egress.

Structural fire protection analysis is separated into four parts: type of construction, structural fire resistance, fire resistance separations, and flammability are reviewed. Building V was constructed as a Type IB structure and met all requirements for area and height. Protecting the structural members with 1- and 2-hour fire ratings were also compliant for Type IB construction. The required separations for shafts and uses were also properly designed with 1- and 2-hour fire protected separations. Lastly, flammability of interior finish materials was limited by using Class A products only.

The fire alarm system analysis is broken up into six areas: fire alarm types, initiating devices, notification devices, fire alarm system design, smoke control, and inspection, testing, and maintenance. Building V was properly provided with a manual fire alarm with automatic smoke detection and an emergency voice/alarm communication system as required by code. The initiating and notification devices were provided in proper locations with compliant spacing. The fire alarm system was also designed properly for operating in an emergency condition without building power. Required compartmentation for smoke control was met with the use of automatic closing doors and fire/smoke dampers. Lastly, proper inspection, testing, and maintenance will ensure that the building maintains a functional fire alarm system.

The fire sprinkler system analysis is also divided into six areas: fire sprinkler type, standpipe type, fire sprinkler design criteria, hydraulic calculations, sprinkler components, and inspection, testing, and maintenance. A wet automatic sprinkler system was installed per NFPA-13 as required by code. Class I standpipes were installed within all interior exit stairs as well. Each area was analyzed for their occupancy group hazard and was found to provide enough water for the demand of the sprinkler system. Lastly, proper inspection, testing, and maintenance will ensure that the building maintains a functional fire sprinkler system.

The last portion of the prescriptive design analyzed the means of egress of the building. An occupant load calculation was used to determine the required number of exit access doorways, the required exit access and stair widths, travel distances, common paths of egress, and dead ends. Once the exit access was analyzed, the required number of exits and required exit width was found. The building was found to be fully compliant with means of egress as required by Chapter 10 of the California Building Code. Occupants would be able to safely egress to the public way.

The performance based design analyzed a design fire scenario of a couch within the corridor. The couch was assumed to be a composite of flexible polyurethane and cellulose material. An analysis of required safe egress time (RSET) and available safe egress time (ASET) was completed to determine if occupants would be able to safely evacuate the building in the case of

a fire. The ASET was calculated based on three tenability criteria of visibility, temperature, and carbon monoxide concentration. All conditions were analyzed at six feet above the walking surface. In order to maintain tenable conditions, visibility could not be reduced to less than 33 feet, temperature needed to be less than 176° F, and carbon monoxide concentrations had to be less than 1,000 ppm. The design fire scenario was modeled using Pyrosim and time to reach untenable conditions were found. Based on the results, visibility was reduced to less than 33 feet within 120 seconds of the start of the fire. Temperature exceeded 176° F within 180 seconds of the start of the fire. Lastly, toxicity was able to be maintained at less than 1,000 ppm CO during the duration of the simulation.

The RSET was calculated based on three movement time frames: detection time, pre-evacuation time, and travel time. Detection time was calculated using a detact model and found that sprinkler activation occurred within 117 seconds of the fire being started. The pre-evacuation time was based on data collected in research in which an average of 186 seconds was found for a mid-rise apartment with good alarm performance. Lastly, the travel time was modeled using Pathfinder to determine the required time to safely egress the building. The travel time was found to be 213 seconds. The occupants would need 516 seconds to safely evacuate the building before the effects of the fire would have made conditions untenable for evacuation.

Based on the design report, two recommendations would be made to help maintain a safe environment for the occupants of the building. The first recommendation would be to remove the furniture within the rated corridor and limit the use to circulation only. A second alternative recommendation would be to create an enclosed room for the alcove and provide a rated separation between the lounge area and the rated corridor.

TABLE OF CONTENTS

INTRODUCTION

Building V is part of a larger project that includes the construction of nine buildings proposed over a city block that will expand the campus footprint providing new undergraduate and graduate student housing with various mixed uses with an emphasis on providing safe student housing. Figure 1 shows the location of the building, circled in red, in relation to the project site. The overall site has 36 retail spaces covering over 104,000 SF of space, a state of the art 30,000 SF fitness center, 467 parking spaces, an 8,000 SF dining hall with capacity for over 400 students, and housing for up to 5,200 students and over 250 faculty/student family apartments. Additionally, new open space is provided for a farmer's market, concerts, outdoor lectures, and special events.

Figure 1: Aerial View of Overall Project Site (Building V in red)

This report will provide an analysis of Building V based on both prescriptive and performance-based design approaches. The prescriptive design will follow a step by step analysis based on the 2013 California Building Code with all applicable standards adopted by the code. The prescriptive design will look in detail to the allowable area and height based on the type of construction, fire ratings and separations, fire alarm system design, smoke control, automatic sprinkler system design, flammability assessment, and required egress widths and travel distances. The performance-based design will utilize a challenging fire scenario based on design assumptions prescribed by NFPA 101. The analysis will model a fire that will test the building system and layout to determine if occupants that are not intimate with the fire will be able to egress the building safely within the allowable safe egress time.

PROJECT DESCRIPTION

Completed in 2018, Building V is a 189,296 SF 5-story mixed use building of Type IB construction providing freshman honor students housing. The building provides a distinctive collegiate-style architecture that is aligned with the university's traditions while providing modern facilities and residential accommodations. Figure 2 shows a front view of the building along with the 145-foot tall Gothic-style clock tower.

Figure 2: Front View of Building V

The ground floor includes a dining hall to the west, meeting rooms to the northeast, retail to the east, bicycle parking to the southeast, a residential community lobby to the south, and a housing customer service center to the south as well. Figure 3 shows the overall first floor layout.

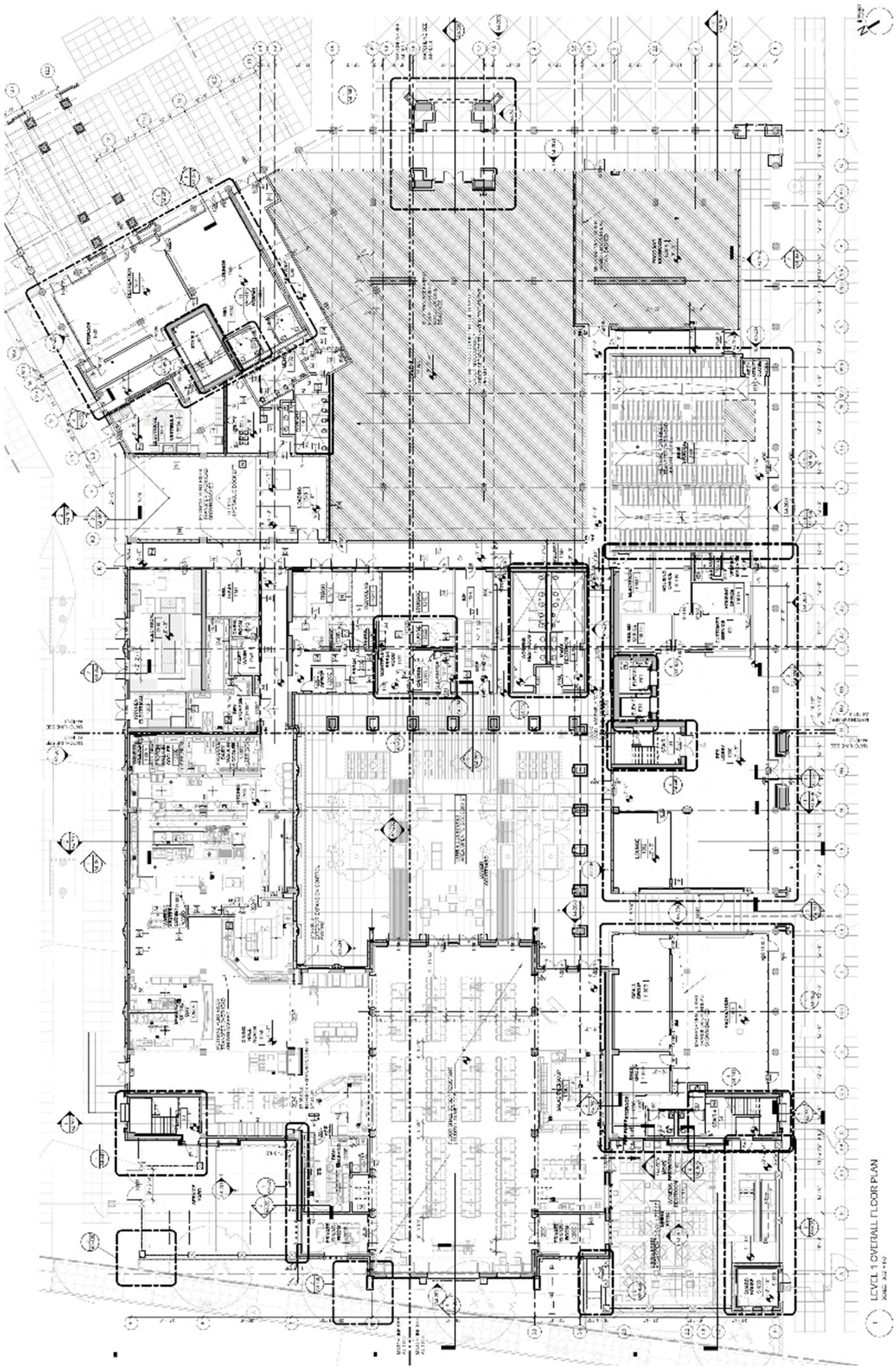


Figure 3: Level 1 Overall Floor Plan

An area of the first floor that contains a large assembly of students is the dining hall. The dining hall is 8,000 SF with 40’ high ceilings and has a capacity to seat over 600 students. Figure 4 shows an overall floor plan of the dining hall while Figure 5 shows the actual dining hall.

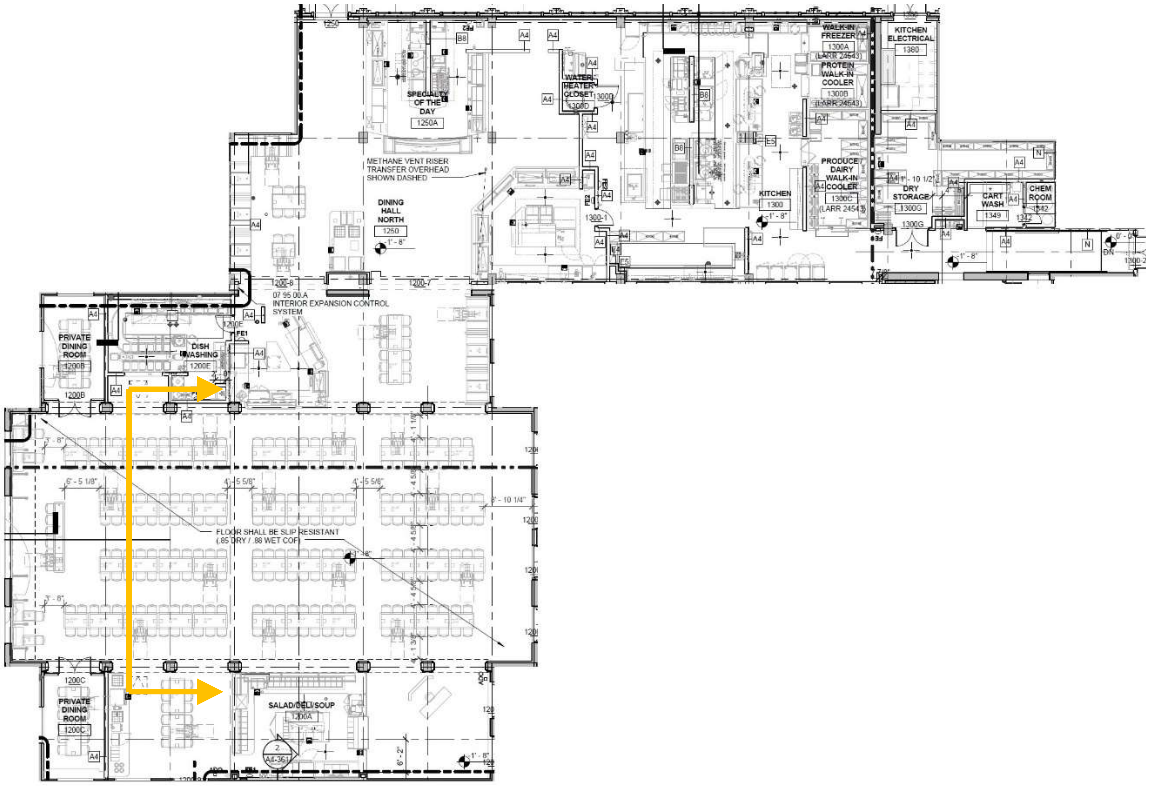


Figure 4: Dining Hall and Kitchen Floor Plan

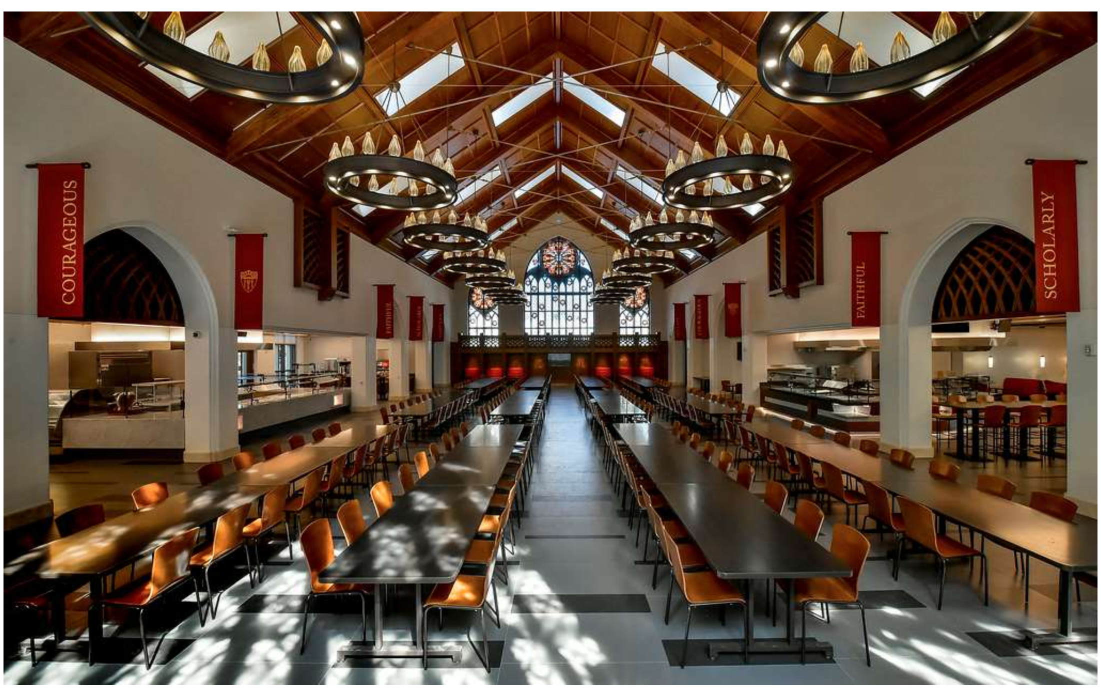


Figure 5: Dining Hall

The second through fifth floors are residential floors with 145 sleeping units set up as three, four, or eight person suites providing housing for 555 honors students. Each floor additionally has a laundry room, student lounges, and back of house areas, such as a janitor's room, electrical room, and trash room. Figure 6 shows an overall floor plan of the second floor.

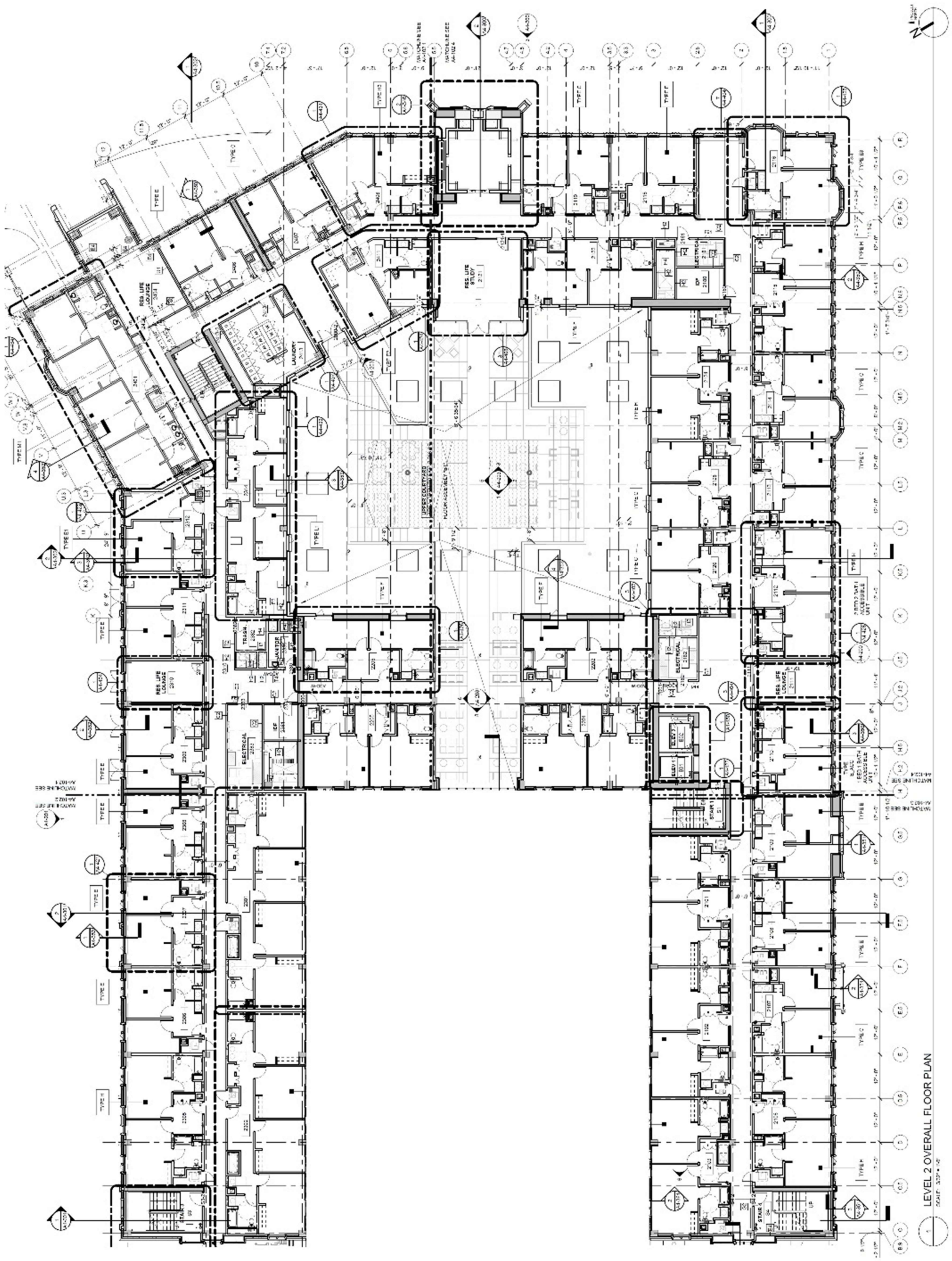


Figure 6: Level 2 Overall Floor Plan

In the center of the second floor is a large outdoor courtyard for student use sized for over 200 occupants. Figure 7 shows an overall floor plan of the outdoor courtyard and Figure 8 shows the actual courtyard.

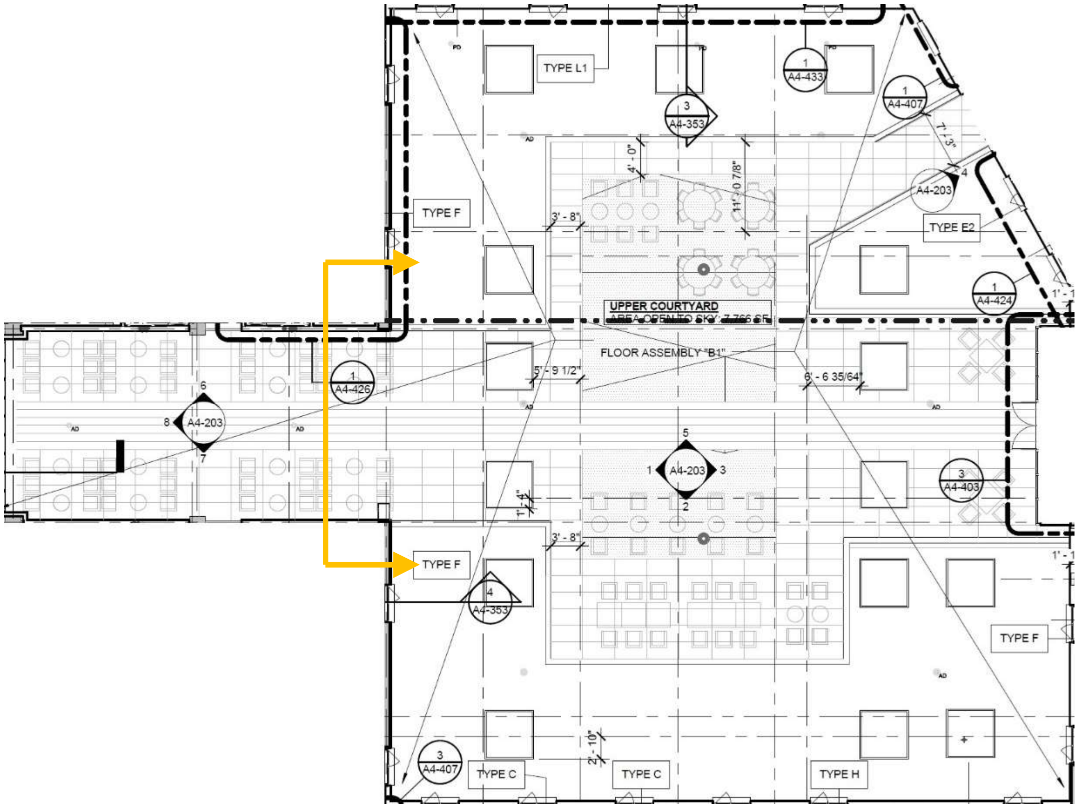


Figure 7: Level 2 Outdoor Courtyard Floor Plan

Figure 8: Level 2 Outdoor Courtyard

PRESCRIPTIVE DESIGN
The 2013 California Building Code provides for a systematic prescriptive method of compliance for safety when designing a building. The driving force behind the requirements within the code are based on the occupancy groups within the building and the number of occupants. The prescriptive design portion of this report is broken into four sections. The first section will cover the structural fire protection within the building based on the type of construction. The second section will cover the fire alarm system design based on the occupancy groups. The third section will cover the automatic sprinkler system design. Lastly, the fourth section will cover the required means of egress for the occupants of the building.

STRUCTURAL FIRE PROTECTION
The California Building Code prescribes nine different types of construction, one of which must be selected when designing a structure. The minimum type of construction required for a building is based on the occupancy groups, area, and height of the building. Once the type of construction has been selected, the requirements for fire proofing the structure can be found. This section will detail compliance for the selected type of construction, the structural fire protection requirements for the selected type of construction, required fire protection ratings within the building, and an assessment on flammability.

Type of Construction:
Constructed of concrete, Building V was designed to the requirements of Type IB construction based on the 2013 California Building Code. Table 1 shows the types of occupancy groups and their associated areas broken down per floor. The overall building has mixed occupancies of A-2, A-3, B, M, R-2, and S-2 occupancy groups. The largest floor is Level 1 with 53,536 SF with the building having an overall area of 189,296 SF.

Table 1: Occupant Floor Area Breakdown per Floor

								FLOOR AREA BUILDING CODE
			Use Group	A-2	(Student) Dining			8,973
			Use Group	M	General Retail			8,667
ACTUAL FLOOR AREA (gross floor area / floor)	TYPE IB	FLOOR LEVEL 1	Use Group	A-2	Food and Beverage			2,296
			Use Group	A-2	Courtyard Open to Sky			0
			Use Group	A-3	Assembly/Covered Outdoor Space			7,066
			Use Group	B	Support/Horiz. Circ.			17,318
			Use Group	B	Guard House (Separate Permit)		127	0
			Use Group	S-2	Utility			3,833
			Use Group	S-2	Bike Parking			2,752
			Use Group	S-2	Loading Dock			1,530
			Use Group	S-2	Storage			1,099
			Use Group	-	Stair/Elevator/Shaft			0
						FLOOR LEVEL 1 - TOTAL		53,536
ACTUAL FLOOR AREA (gross floor area / floor)	TYPE IB	FLOOR LEVEL 2	Use Group	A-3	Assembly/Covered Outdoor Space			1,149
			Use Group	A-3	Courtyard Open to Sky			0
			Use Group	B	Support			634
			Use Group	R-2	Residential/Horiz. Circ./Res. Life			33,248
			Use Group	S-2	Utility			771
			Use Group	-	Stair/Elevator/Shaft			0
						FLOOR LEVEL 2 - TOTAL		35,802
ACTUAL FLOOR AREA (gross floor area / floor)	TYPE IB	FLOOR LEVEL 3	Use Group	B	Support			620
			Use Group	R-2	Residential/Horiz. Circ./Res. Life			35,322
			Use Group	S-2	Utility			767
			Use Group	-	Stair/Elevator/Shaft			0
						FLOOR LEVEL 3 - TOTAL		36,709
ACTUAL FLOOR AREA (gross floor area / floor)	TYPE IB	FLOOR LEVEL 4	Use Group	B	Support			622
			Use Group	R-2	Residential/Horiz. Circ./Res. Life			34,691
			Use Group	S-2	Utility			774
			Use Group	-	Stair/Elevator/Shaft			0
						FLOOR LEVEL 4 - TOTAL		36,087
ACTUAL FLOOR AREA (gross floor area / floor)	TYPE IB	FLOOR LEVEL 5	Use Group	B	Support			620
			Use Group	R-2	Residential/Horiz. Circ./Res. Life			25,772
			Use Group	S-2	Utility			770
			Use Group	-	Stair/Elevator/Shaft			0
						FLOOR LEVEL 5 - TOTAL		27,162
GROSS BUILDING FLOOR AREA						GRAND TOTAL		189,296

Table 2 shows the actual number of stories and building height. The structure is 5-stories high and has a height of 62’-6.75”.

Table 2: Number of Stories and Building Height (FT)

GENERAL BUILDING HEIGHTS AND AREAS			
ACTUAL STORIES	TYPE IB TOTAL		5
ACTUAL BUILDING HEIGHT (BUILDING CODE)	AVERAGE HEIGHT OF HIGHEST ROOF SURFACE (MEASURED FROM GRADE PLANE-185.06)		62'-6 3/4"
ACTUAL BUILDING HEIGHT (ZONING CODE)	TOP OF TOWER (DIR-2013-4074-SPP-SPPA CONDITIONS #12, TOWER, MEASURED FROM LOWEST POINT-183.25)		149'-10 1/2"
	TOP OF FINIALS (DIR-2013-4074-SPP-SPPA CONDITIONS #12, TOWER, MEASURED FROM LOWEST POINT-183.25)		86'-10 1/2"
	TOP OF MANSARDS (DIR-2013-4074-SPP-SPPA CONDITIONS #12, TOWER, MEASURED FROM LOWEST POINT-183.25)		76'-1 1/4"

Based on the occupancy groups and type of construction, the California Building Code provides limitations on floor area, number of stories, and building height. Table 3 summarizes Table 503 {2013 CBC} which shows the allowable area per floor, allowable number of stories, and the allowable height based on Type IB construction.

Table 3: Allowable Area per floor, Stories, and Height based on Type IB Construction

Occupancy Group	Area (SF)	Stories	Height (FT)
A-2	Unlimited	11	160
A-3	Unlimited	11	160
B	Unlimited	11	160
M	Unlimited	11	160
R-2	Unlimited	11	160
S-2	79,000	11	160

All occupancy groups other than S-2 are unlimited in area while the S-2 occupancy areas are limited to 79,000 SF per floor. However, section 506.3 {2013 CBC} allows for an increase to the allowable area found in Table 3 when automatic sprinklers designed to NFPA-13 are provided within the building. Since Building V was provided with automatic sprinklers, the allowable area can be increased by a factor of 3. This results in an allowable area for the S-2 occupancy groups to be 237,000 SF per floor.

Because the modified values in Table 3 were not exceeded, Building V complies with all prescriptive requirements for nonseparated use for allowable area, height and stories for the given type of construction.

Structural Fire Resistance:
The California Building Code defines Type I construction as containing building elements of noncombustible materials for those elements listed in Table 601 {2013 CBC}. Table 4 shows the required fire resistance rating requirements for the listed building elements. The rating of exterior nonbearing walls are based on the fire separation distance to other buildings or property lines. Building V has a fire separation distance of greater than 30’ in all directions, thus the nonbearing exterior walls are not required to be rated.

Table 4: Fire-Resistance Rating Requirements for Building Elements (Hours)

Building Element	Type IB
Primary Structural Frame	2
Bearing walls – Exterior	2
Bearing walls – Interior	2
Nonbearing walls and partitions – Exterior: FSD > 30’	0
Nonbearing walls and partitions – Interior	0
Floor construction and associated secondary members	2
Roof construction and associated secondary members	1

The primary structural frame, bearing walls, floors, and roof were made of structural concrete of Type II cement and aggregates conforming to ASTM C-33. The concrete is designed for a minimum compressive strength at 28 days of 5000 psi with a density of 150 pcf. The reinforcing steel rebar complies with ASTM A615 Grade 60 and maintains a concrete cover of 1”-1.5”. Table 5, found in Table 722.2.2.1 and 722.2.1.1 {2013 CBC}, summarizes the required slab and wall thicknesses in inches for the required fire rating. Table 6, found in Table 722.2.4 {2013 CBC}, provides the required concrete column thickness in inches for the required fire rating.

Table 5: Min. Slab/Wall Thickness (in)

	Fire Resistance Rating	
Concrete Type	1-Hour	2-Hours
Siliceous	3.5	5

Table 6: Min. Column Thickness (in)

	Fire Resistance Rating
Concrete Type	2-Hours
Siliceous	10

Building V has two-way floor slabs and bearing walls with a minimum of 8” thick concrete which exceed the required thickness of 5” for a 2-hour rating required by Table 5. The roof is constructed of a minimum 4” thick concrete which provides the required 1-hour fire resistance rating as shown in Table 5. Lastly, the concrete columns are a minimum 18” thick which exceeds the minimum 10” requirement to achieve a rating of 2-hours from Table 6.

Fire Resistance Separations:

The requirements for fire resistance rating of interior nonbearing partitions are found in various parts of the California Building Code. Shaft protection (trash chutes, elevators, and interior stairs), sleeping unit separations, corridor rating, and trash chute access rooms are the four areas separation will be required for this building. Protection of shafts are found in section 713.4 {2013 CBC} which requires shafts that connect more than 4-stories to be a 2-hour fire barrier. The requirement for separation of sleeping units is found in section 420.2 {2013 CBC} which requires a 1-hour fire partition. Corridors are required to be a 1-hour fire partition per Table 1018.1 {2013} due to the corridor serving greater than 10 occupants. Lastly, section 713.13.3 {2013 CBC} requires that all trash chutes located in a corridor be provided with an access room that is required to be separated by a 1-hour fire barrier.

The fire barriers found in Building V are constructed of metal studs spaced 16” on center wrapped with 1 or 2 layers of Type “X” gypsum wallboard on both sides, providing a 1- or 2-hour fire resistance rating respectively. The Type “X” gypsum wallboard is required to span the full height of the story from the floor to the underside of the floor above. Figure 9 shows a typical construction detail for the 2-hour fire barrier. Table 10, found in Table 716.5 {2013 CBC}, shows the required door ratings for openings located within the fire barrier.

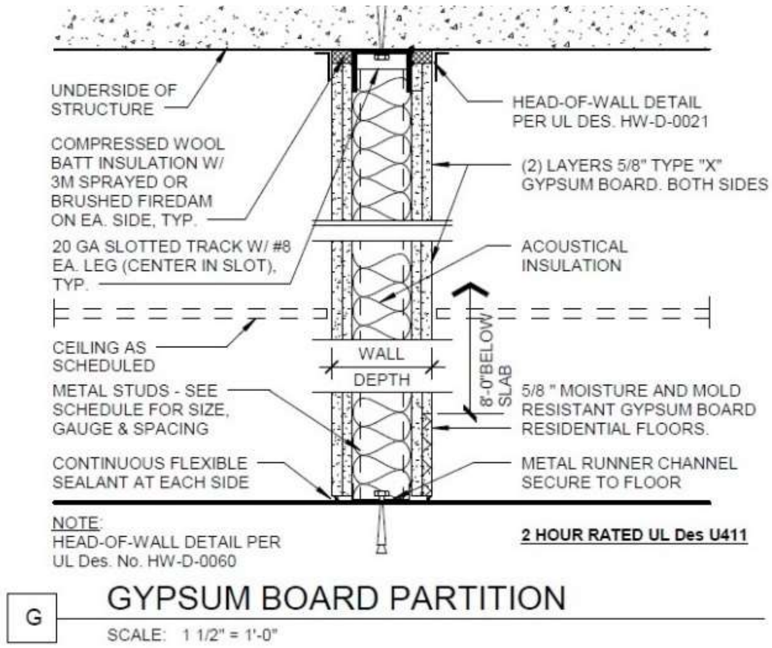


Figure 9: 2-Hour Fire Barrier Detail

The fire partitions in Building V are also constructed of metal studs spaced 16” on center but only wrapped with 1 layer of Type “X” gypsum wallboard on both sides, providing a 1-hour fire resistance rating. The Type “X” gypsum wallboard is only required to span from the floor to the underside of the rated ceiling or floor above. Figure 10 shows a typical construction detail for the 1-hour fire partition. Table 10, found in Table 716.5 {2013 CBC}, shows the required door ratings for openings located within the fire partition.

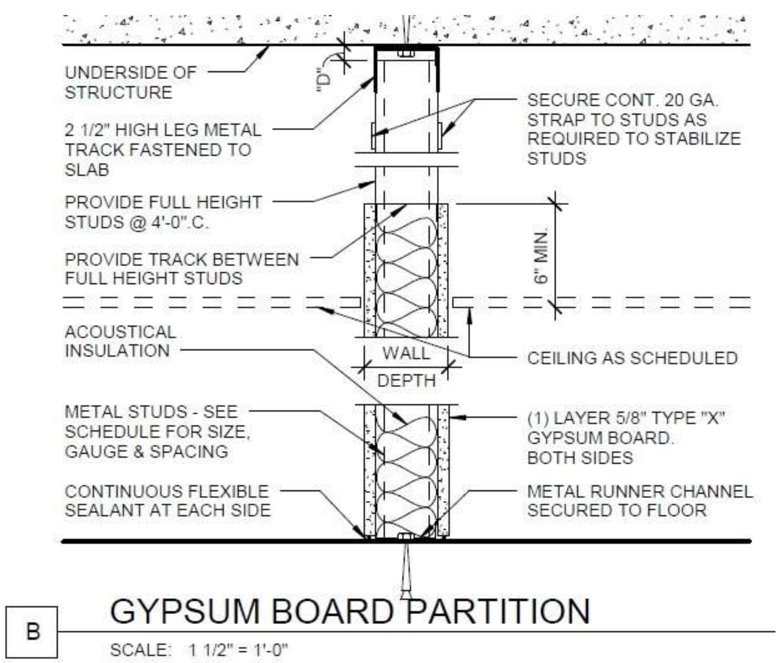


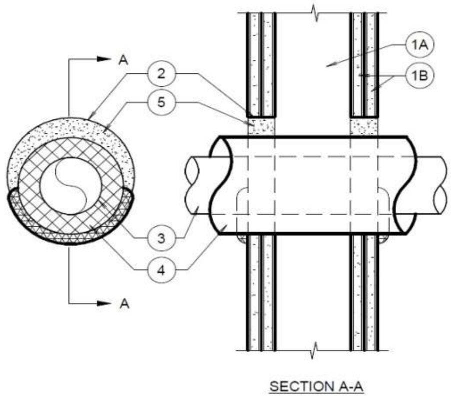
Figure 10: 1-Hour Fire Partition Detail

Table 10: Opening Fire Protection Assemblies/Ratings

Type of Assembly	Wall Assembly Rating (hours)	Fire Door Rating (min)
Fire Barrier	1	45
Fire Barrier	2	90
Fire Partition	1	20

Penetrations through the walls and slabs are required by section 713.3.1.2 and 713.4.1.1.2 {2013 CBC} to be tested in accordance with ASTM E814 or UL 1479 and have a F rating of not less than the required fire resistance rating of the wall or floor being penetrated. All penetrations are contained within a Schedule 10 or heavier 12" or smaller nominal diameter steel pipe. The void or cavity areas for wall penetrations are filled with a HILTI sealant with a minimum depth of 1-1/4" with a minimum ½" diameter bead of sealant applied on both surfaces of the wall. The void or cavity areas for floor penetrations are filled with a HILTI mortar with a minimum thickness of 2-1/2". Figure 11 shows a typical detail for protecting a wall penetration while Figure 12 shows a typical slab penetration protection detail.

System No. W-L-7018
F Rating - 2 Hr
T Rating - 1 1/2 Hr



1. **Wall Assembly** — The 2 hr fire-rated gypsum wallboard/stud wall assembly shall be constructed of the materials and in the manner specified in the individual U300 or U400 Series Wall and Partition Designs in the UL Fire Resistance Directory and shall include the following construction features:

A. **Studs** — Wall framing may consist of either wood studs or steel channel studs. Wood studs to consist of nom 2 by 4 in. lumber spaced 16 in. OC. Steel studs to be min 2-1/2 in. wide and spaced max 24 in. OC.

B. **Gypsum Board*** — Two layers of nom 5/8 in. thick gypsum wallboard as specified in the individual Wall and Partition Design No. Max diam of opening is 9 in.

2. **Metallic Sleeve** — Cylindrical sleeve fabricated from min 0.016 in. thick (No. 28 gauge) galv steel sheet steel and having a min 2 in. lap along the longitudinal seam. Length of sleeve to be 1/8 in. less than thickness of wall. Sleeve to be installed by coiling the sheet metal to a diam smaller than the through opening, inserting the coil through the openings and releasing the coil to let it uncoil against the circular cutouts in the gypsum wallboard layers.

3. **Steel Duct** — Nom 6 in. diam (or smaller) No. 28 gauge (or heavier) galv steel duct to be installed concentrically within the firestop system. Duct to be rigidly supported on both sides of the wall assembly.

4. **Pipe Covering*** — Nom 1 in. thick hollow cylindrical heavy density (3.5 pcf) glass fiber units jacketed on the outside with an all service jacket. Longitudinal joints sealed with metal fasteners or factory-applied self-sealing lap tape. Tranverse joints secured with metal fasteners or with butt tape supplied with the product. The annular space between the insulated pipe and the steel sleeve shall be min 0 in. (point contact) to max 1 in. See Pipe Equipment Covering — Materials — (BRGU) Category in the Building Materials Directory for names of manufacturers. Any pipe covering material meeting the above specifications and bearing the UL Classification Marking with a Flame Spread Index of 25 or less and a Smoke Developed Index of 50 or less may be used.

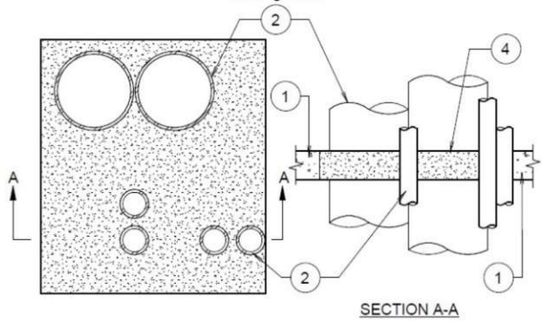
5. **Fill, Void or Cavity Material*** — Sealant — Min 1-1/4 in. depth of sealant applied within the annulus, flush with each surface of the wall assembly. At the point contact location between insulated pipe and wall, a min 1/2 in. diam bead of sealant shall be applied on both surfaces of wall, lapping 1/4 in. beyond the periphery of the opening.

HILTI CONSTRUCTION CHEMICALS, DIV OF HILTI INC — FS-ONE Sealant

*Bearing the UL Classification Mark

Figure 11: Wall Penetration Protection Detail

System No. C-AJ-1140
F Rating - 3 Hr
T Rating - 0 Hr



1. **Floor or Wall Assembly** — Min 2-1/2 in. (63 mm) thick reinforced lightweight or normal weight (100-150 pcf or1600-2400 kg/m3) concrete. Wall may also be constructed of any UL Classified Concrete Blocks *. Max area of opening is 1024 sq in. (.66 sq m) with max dimension of 32 in. (81.3 cm).See Concrete Blocks (CAZT) category in the Fire Resistance Directory for names of manufacturers.

2. **Through Penetrants** -- One or more penetrants to be installed in opening. Min clearance between pipes, conduits or tubing is 0 in. (0 mm). (point contact). Min clearance between pipes, conduit or tubing and periphery of through opening is 1 in. (25 mm). Min clearance between pipes, conduit or tubing and periphery of any single surface of through opening is 0 in. (point contact). Pipe, conduit or tubing to be rigidly supported on both sides of floor or wall assembly. The following types and sizes of metallic pipes, conduits or tubing may be used:
A. **Steel Pipe** — Nom 12 in. (305 mm) diam (or smaller) Schedule 10 (or heavier) steel pipe.
B. **Conduit** — Nom 4 in. (102 mm) diam (or smaller) steel electrical metallic tubing or steel conduit.
C. **Copper Tubing** — Nom 4 in. (102 mm) diam (or smaller) Type L (or heavier) copper tubing.
D. **Copper Pipe** — Nom 4 in. (102 mm) diam (or smaller) Regular (or heavier) copper pipe.

3. **Forms** — (Not Shown) — Used as a form to prevent leakage of fill material during installation. Forms to be a rigid sheet material, cut to fit the contour of the penetrating item and positioned as required to accommodate the required thickness of fill material. Forms may be removed after fill material has cured.

4. **Firestop System** — The details of the firestop system shall be as follows:

A. **Packing Material** — (Optional, Not Shown) - For floors greater than 2-1/2 in. (63 mm) thick, mineral wool batt insulation firmly packed into opening as a permanent or temporary form and recessed from the top surface of floor to accommodate the required thickness of the fill material.

B. **Fill, Void or Cavity Material*** — Mortar — Min 2-1/2 in. (63 mm) thickness of fill material applied within the annulus. Fill material is mixed at a rate of 2.5 parts dry mix to one part water by weight in accordance with the installation instructions supplied with fill material.
HILTI CONSTRUCTION CHEMICALS, DIV OF HILTI INC — Type FS635, CP636 or CP637

Figure 12: Slab Penetration Protection Detail

Figure 13 shows the Level 1 floor plan identifying the 1-hour rated separations in red and the 2-hour separations in blue.

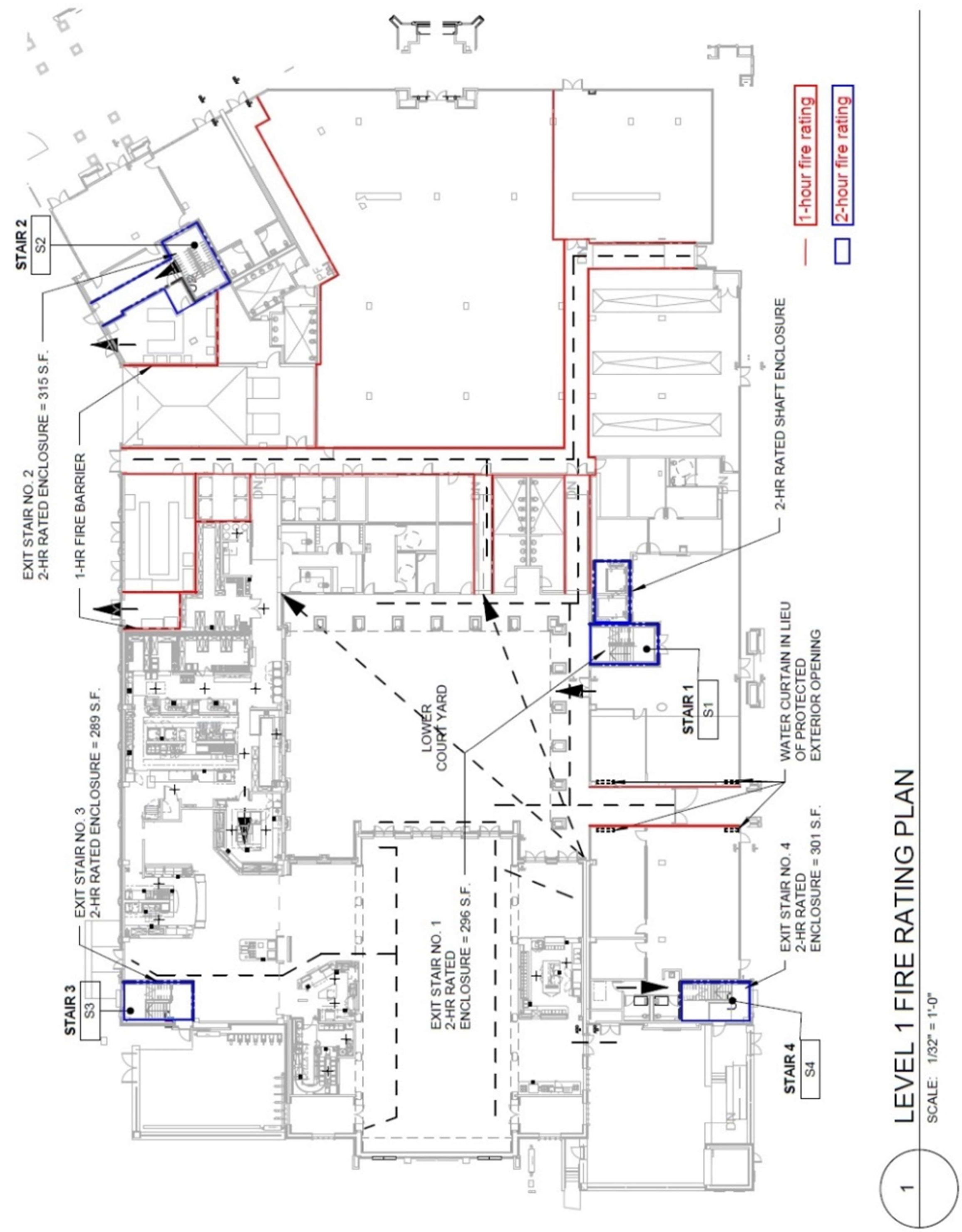


Figure 13: Level 1 Floor Fire Rating Plan

Figure 14 shows the Level 2 floor plan, which would be typical for Levels 2-5, identifying the 1-hour rated separations in red and the 2-hour separations in blue.

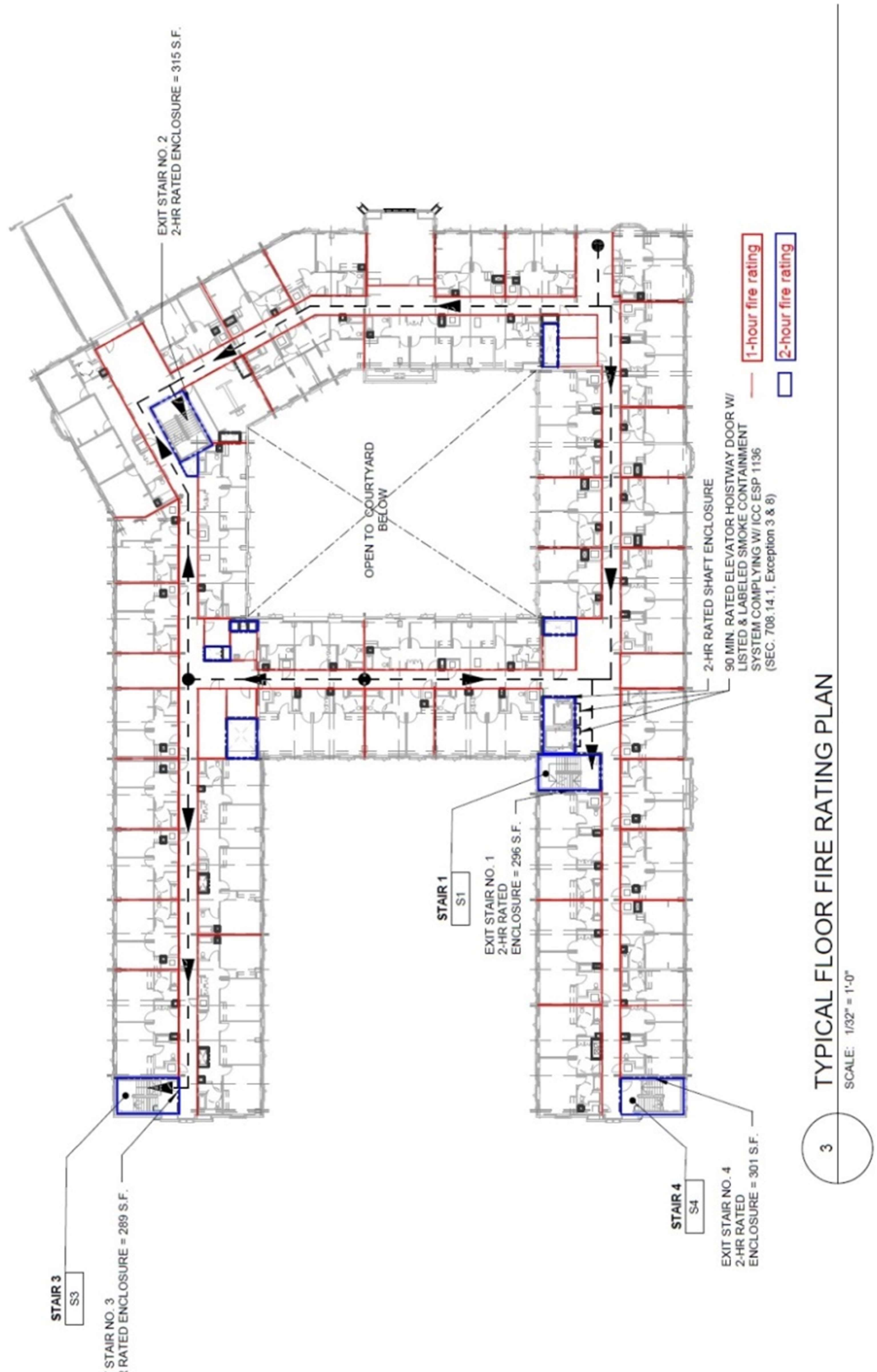


Figure 14: Level 2 Floor Fire Rating Plan

Flammability:
Flammability is controlled in the California Building Code through the limitations on interior finish. Interior wall and ceiling finish materials are classified in accordance with ASTM E84 or UL 723. They are divided into 3 classes:

Class A: Flame spread index 0-25; smoke developed index 0-450.
Class B: Flame spread index 26-75; smoke developed index 0-450.
Class C: Flame spread index 76-200; smoke developed index 0-450.

The requirements for interior finish are based on the occupancy group, the use of the space, and whether the building has a sprinkler system or not. Table 11, found in Table 803.9 {2013 CBC} summarizes the requirements for a building with sprinklers provided throughout.

Table 11: Interior Wall and Ceiling Finish Requirements by Occupancy

Occupancy Group	Exit Stairway	Corridors	Rooms and Spaces
A-2 / A-3	B	B	C
B / M	B	C	C
R-2 / S-2	C	C	C

Building V was designed conservatively utilizing all Class A finish in all locations.

STRUCTURAL FIRE PROTECTION SUMMARY
In summary, Building V met all prescriptive requirements for structural fire protection. Based on the uses of the building and size of the building, the chosen type of construction is code compliant. Structural and non-structural members were properly sized and protected with concrete or Type “X” gypsum wallboard. Required compartmentation was met through the fire barrier and fire partition constructions. Lastly, flammability was maintained through the use of Class A finish materials. In the next section, the fire alarm system designed per the California Building Code and NFPA 72 will be discussed.

FIRE ALARM SYSTEM
The California Building Code requires a fire alarm system when occupancy groups exceed a given occupant load per the requirements found within section 907 {2013 CBC}. Once the types of fire alarm have been selected, NFPA 72 is the standard used for the design and maintenance of the fire alarm system. This section will take a detailed look into the compliance for the required types of fire alarm systems, initiating and notification devices, design of the fire alarm system, smoke control, and inspection, testing, and maintenance of the fire alarm system.

Fire Alarm Types:
The requirements for a fire alarm system need to be verified against each type of occupancy group and the number of occupants. Section 907.2.1 {2013 CBC} requires that all Group A occupancies with an occupant load of over 300 be provided with a manual fire alarm system. Furthermore, section 907.2.1.1 {2013 CBC} requires that Group A occupancies with over 1,000 occupants shall initiate a signal using an emergency voice/alarm communication system. Section 907.2.9 {2013 CBC} discusses the requirements for Group R-2 occupancies and require a manual fire alarm system in all buildings with more than 16 sleeping units. Section 907.2.9.3 {2013 CBC} also requires automatic smoke detection in Group R-2 college buildings within the following spaces: 1) Common spaces outside of dwelling units and sleeping units, 2) Laundry rooms, mechanical equipment rooms, and storage rooms, and 3) All interior corridors serving sleeping units or dwelling units. Lastly, Section 907.2.11.2 {2013 CBC} requires that single- or multiple-station smoke alarms be installed in the following locations: 1) On the ceiling or wall

outside of each separate sleeping area in the immediate vicinity of bedrooms and 2) In each room used for sleeping purposes.

Initiating Devices:
Initiation of the fire alarm system can be accomplished either manually or automatically. The manual method of activation is through pull stations that are typically required at all exit doors leading to the exterior or to exit stairs. The California Building Code however has an exception for buildings with automatic sprinklers, where a pull station need only be provided where required by the Authority Having Jurisdiction. For Building V, the university has voluntarily added two pull stations, one at the guard station and another next to the fire alarm annunciator panel. Figure 15 shows the Notifier NBG-12LX (CSFM 7150-0028:0199) pull station used in the building.

Figure 15: Notifier NBG-12LX Pull Station

There are two methods for automatically activating the fire alarm system. The first is an opened sprinkler head which will cause the waterflow switch to activate and send a signal to the fire alarm panel. This section however deals with the second type of automatic activation which is through the smoke detectors. Figure 16 shows the Notifier FSP-851 (CSFM 7272-0028:0206) ceiling mounted smoke detectors used in the building.

Figure 16: Notifier FSP-851 Ceiling Mounted Smoke Detector

The Notifier FSP-851 addressable photoelectric smoke detector is a spot type smoke detector. The photoelectric smoke detector is activated when light from a pulsing source is reflected from the smoke particles to the receiving element. These smoke detectors are installed on the ceiling and placed in front of elevators, above the fire alarm control panel, adjacent to doors on magnetic hold, electrical rooms, elevator control rooms, at the top of stairwells, in the residential corridor halls, and in various locations to control the smoke fire dampers.

The stairwell smoke detectors are installed per Health and Safety Code 13113.7 which requires smoke detectors in the common stairwells of apartment complexes. Section 17.4.10 {2013 NFPA 72} allows a detector to be installed in close proximity to an object or space if the intent is to initiate action when smoke or fire threatens a specific object. This is the case for the elevator recall and fire alarm control panel where a smoke detector is placed within 5' of the object. Section 17.7.5.6.5.1 {2013 NFPA 72} provides requirements for smoke detectors used for door release service where a detector shall be required on each side of the doorway.

For the remaining smoke detectors, Section 17.7.3.2.3.1 {2013 NFPA 72} provides a prescriptive design approach for the spacing of smoke detectors. The two requirements are: “1) The distance between smoke detectors shall not exceed a nominal spacing of 30 ft and there shall be detectors within a distance of one-half the nominal spacing, measured at right angles from all walls or partitions extending upward to within the top 15% of the ceiling height. 2) All points on the ceiling shall have a detector within a distance equal to or less than 0.7 times the nominal 30 ft spacing (0.7*S*).”

Figures 20 and 21 below shows the spacing of all initiating devices for Levels 1 and 2. The smoke detectors are highlighted in red while the pull stations are shown with a yellow arrow. Building V is in full compliance with all codes and standards for location and spacing of initiating devices.

Notification Devices:
Once an initiating device has been activated, a signal is sent to the fire alarm control panel which in turn activates the occupant notification system. For Building V, the fire alarm notification is through the Notifier NFS2-3030 (CSFM 7165-0028:0224) fire alarm panel with a Digital Voice Command (DVC) component to provide an emergency voice/alarm communication system. The Notifier DVC supports up to 8 simultaneous messages as well as a built-in

microphone. Section 907.5.2.2 {2013 CBC} requires that the operation of any automatic fire detector, sprinkler waterflow device, or manual fire alarm box shall automatically sound an alert tone followed by voice commands.

In an alarm condition, the system operates by activating both the visible notification appliances (strobes) and the audible notification appliances (speakers). This one-way emergency communication system allows for messages to be delivered either by recording or by a live person. Notification is accomplished through the use of System Sensor strobes and speaker strobes. Models SPSW-P and SPSCW-P (CSFM 7320-1653:0201) are speaker strobes that are either wall or ceiling mounted. Figures 17 and 18 show the two types of speaker strobes used in the building.

Figure 17: Wall Mounted Speaker Strobe

Figure 18: Ceiling Mounted Speaker Strobe

NFPA 72 requires that fire alarm systems provide both visibility and audibility to building occupants. Section 18.4.3.1 {2013 NFPA 72} requires that a fire alarm system have a sound level of at least 15 dB above the average ambient sound level or 5 dB above the maximum sound level having a duration of at least 60 seconds. The pattern of the fire alarm system is also prescribed in Section 18.4.2.1 {2013 NFPA 72} which requires the use of a standard evacuation signal consisting of a three-pulse temporal pattern. Figure 19 shows a typical Temporal-3 pattern.

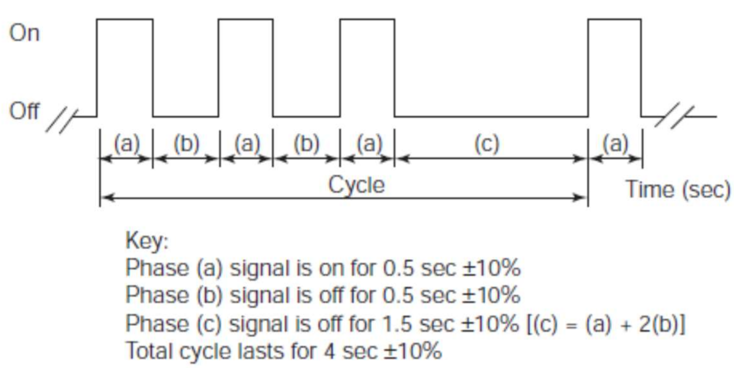


Figure 19: Fire Alarm Temporal-3 Pattern

Visible notification is through the use of strobes, either wall or ceiling mounted. Section 18.5.3 {2013 NFPA 72} lists the requirements for strobes: 1) flash rate shall not exceed 2 Hz nor less than 1 Hz, 2) maximum pulse duration shall be 0.2 second with a maximum duty cycle of 40%, and 3) pulse duration shall be defined as the time interval between initial and final points of 10% of maximum signal. The lights are also required to be clear or nominal white and shall not exceed 1000 candela. Tables 12 and 13 show the effective distance wall and ceiling mounted strobes are able to reach with a given candela rating.

Table 12: Wall Mounted Strobe Coverage

Maximum Room Size		*Minimum Required Light Output [Effective Intensity (cd)]*	
ft	*m*	*One Light per Room*	*Four Lights per Room (One Light per Wall)*
20 × 20	6.10 × 6.10	15	NA
28 × 28	8.53 × 8.53	30	NA
30 × 30	9.14 × 9.14	34	NA
40 × 40	12.2 × 12.2	60	15
45 × 45	13.7 × 13.7	75	19
50 × 50	15.2 × 15.2	94	30
54 × 54	16.5 × 16.5	110	30
55 × 55	16.8 × 16.8	115	30
60 × 60	18.3 × 18.3	135	30
63 × 63	19.2 × 19.2	150	37
68 × 68	20.7 × 20.7	177	43
70 × 70	21.3 × 21.3	184	60
80 × 80	24.4 × 24.4	240	60
90 × 90	27.4 × 27.4	304	95
100 × 100	30.5 × 30.5	375	95
110 × 110	33.5 × 33.5	455	135
120 × 120	36.6 × 36.6	540	135
130 × 130	39.6 × 39.6	635	185

Table 13: Ceiling Mounted Strobe Coverage

Maximum Room Size		*Maximum Lens Height**		*Minimum Required Light Output (Effective Intensity); One Light (cd)*
ft	*m*	*ft*	*m*	
20 × 20	6.1 × 6.1	10	3.0	15
30 × 30	9.1 × 9.1	10	3.0	30
40 × 40	12.2 × 12.2	10	3.0	60
44 × 44	13.4 × 13.4	10	3.0	75
20 × 20	6.1 × 6.1	20	6.1	30
30 × 30	9.1 × 9.1	20	6.1	45
44 × 44	13.4 × 13.4	20	6.1	75
46 × 46	14.0 × 14.0	20	6.1	80
20 × 20	6.1 × 6.1	30	9.1	55
30 × 30	9.1 × 9.1	30	9.1	75
50 × 50	15.2 × 15.2	30	9.1	95
53 × 53	16.2 × 16.2	30	9.1	110
55 × 55	16.8 × 16.8	30	9.1	115
59 × 59	18.0 × 18.0	30	9.1	135
63 × 63	19.2 × 19.2	30	9.1	150
68 × 68	20.7 × 20.7	30	9.1	177
70 × 70	21.3 × 21.3	30	9.1	185

Building V is in full compliance with all codes and standards for location and spacing of notification devices for both audibility and visibility.

Figure 20 shows the location and spacing of all notification devices for Level 1. The strobes and speaker strobes are highlighted in blue.

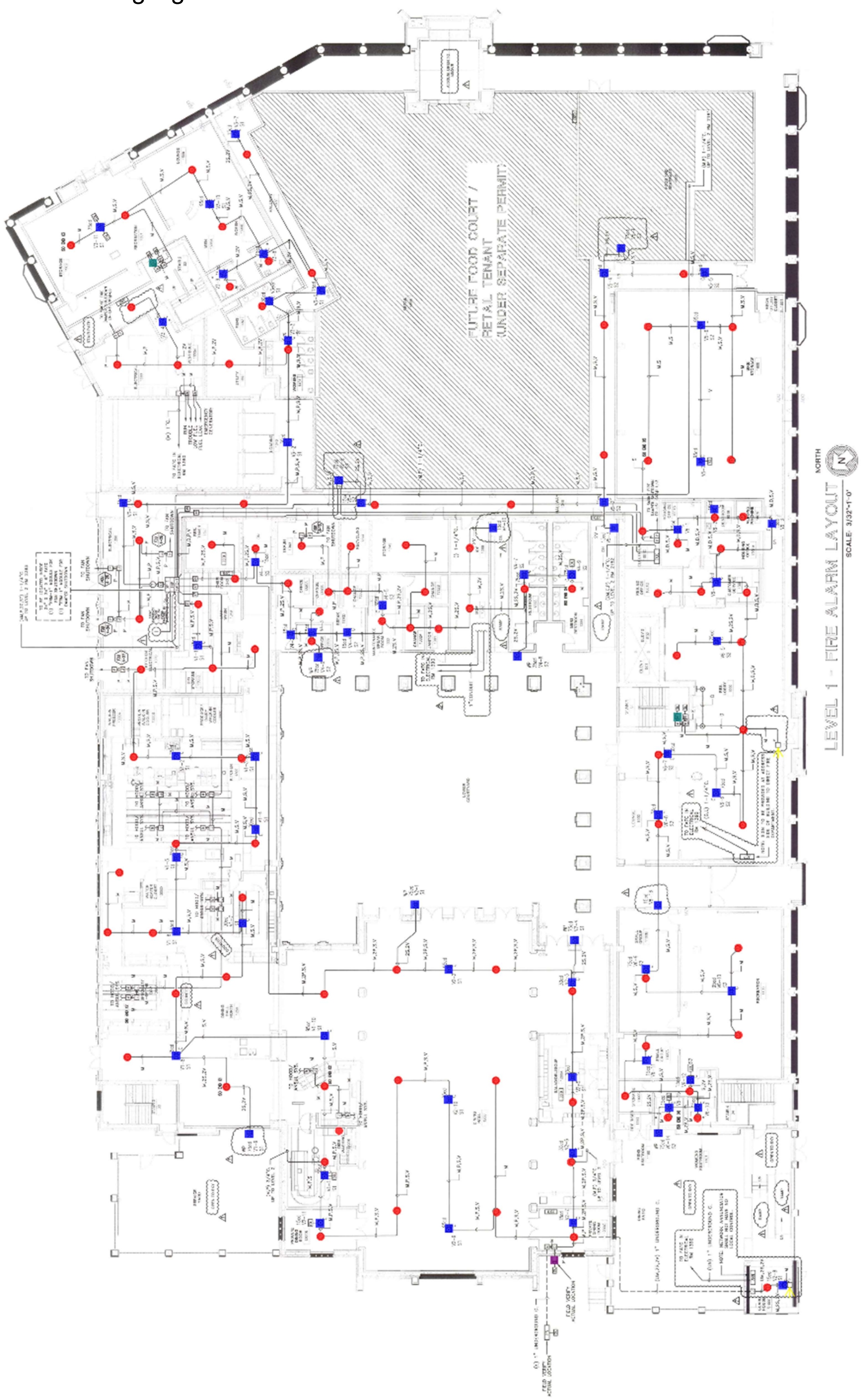


Figure 20: Level 1 Fire Alarm System Layout

Figure 21 shows the location and spacing of all notification devices for Level 2, which would be typical for Levels 2-5, The strobes and speaker strobes are highlighted in blue.

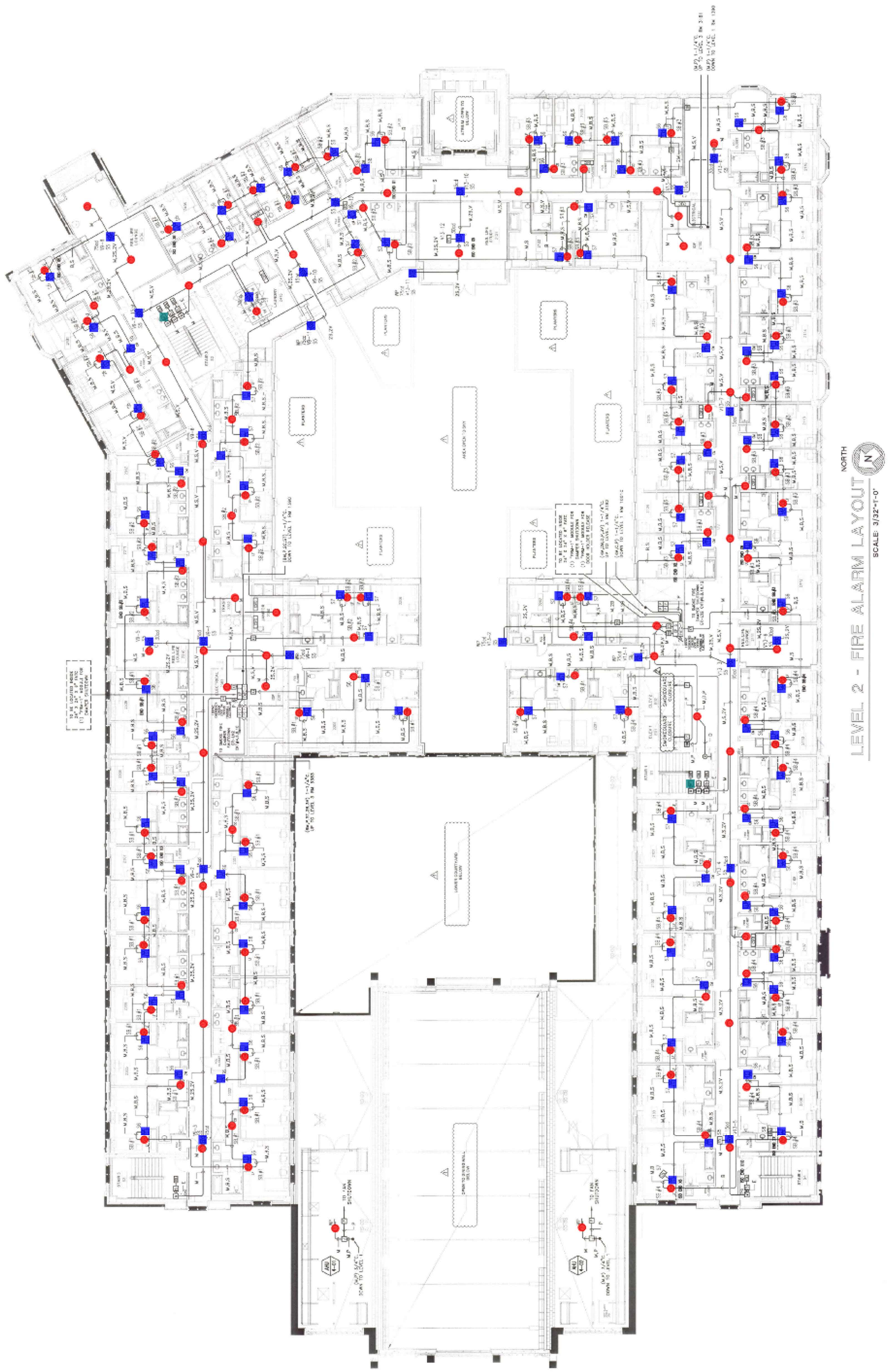


Figure 21: Level 2 Fire Alarm System Layout

Fire Alarm System Design:
Building V has been designed with a manual fire alarm system with automatic smoke detection and an emergency voice/alarm communication system for occupant notification in accordance with NFPA 72. All initiating devices, both manual and automatic, send a signal to the Notifier NFS2-3030 fire alarm panel located within the electrical room. A Notifier RSE-L-GR-GP4-DF-SEC-LCD matrix annunciator is located in the front lobby at the entrance of the building. This annunciator provides complete control of the fire alarm system displaying the status of the alarm as well as controls for the emergency voice communicator. Table 14 shows the sequence of operations for the fire alarm system.

Table 14: Fire Alarm Sequence of Operations

	Control Panel - Alarm	Control Panel - Supervisory	Activate General Alarm	Shut Down HVAC	Close Smoke/Fire Dampers	Activate Elevator Recall	Release Smokeguard	Release Door Holders
Manual Pull Station	X		X	X	X			X
Area Smoke Det.	X		X	X	X			X
Area Heat Det.	X		X	X	X			X
Duct Det.	X		X	X	X			X
Lobby Smoke Det.	X		X	X	X	X	X	X
Water Flow Switch	X		X	X	X			X
Tamper Switch		X						
Special Ext. System	X		X	X	X			X

In the event an actual alarm condition occurs, the building goes into general alarm and all floors are evacuated. The central station is notified of the alarm condition and the local fire department is also notified that there is a fire within the building. The waterflow tamper switch only sends out a supervisory signal to the central station that there is a problem with the system, at which point a runner is dispatched to identify the cause of the problem. In the event of power failure, the fire alarm system must have a secondary power supply capable of keeping the system on standby for 24 hours and a 15 minute alarm. Table 15 shows a selected voltage drop calculation while Table 16 provides a selected secondary power supply battery calculation for the system.

Table 15: Voltage Drop Calculation

POWER SUPPLY EXTERNAL LOAD — **ACPS-610 #3 LEVEL-2 ELEC. RM 2383**

EQUIPMENT MODEL	TOTAL DEVICES	DEVICE CURRENT	TOTAL CURRENT	V9		V10		V11		V12	
				QTY.	AMPS	QTY.	AMPS	QTY.	AMPS	QTY.	AMPS
SPSCW-P 15cd SPEAKER/STROBE (CEILING) STROBE ONLY	26	0.066	1.716	6	0.396	7	0.462	7	0.462	6	0.396
SPSCW-P 30cd SPEAKER/STROBE (CEILING) STROBE ONLY	11	0.094	1.034	2	0.188	3	0.282	3	0.282	3	0.282
SPSCW-P 75cd SPEAKER/STROBE (CEILING) STROBE ONLY	2	0.158	0.316	2	0.316	0	0.000	0	0.000	0	0.000
SPSCW-P 95cd SPEAKER/STROBE (CEILING) STROBE ONLY	1	0.181	0.181	0	0.000	1	0.181	0	0.000	0	0.000
SPSRK 75cd WEATHERPROOF SPEAKER/STROBE STROBE ONLY	3	0.158	0.474	2	0.316	0	0.000	0	0.000	1	0.158
	43		3.721 A								

VOLTAGE DROP CALCULATIONS

	V9	V10	V11	V12
DISTANCE (FEET)	665 FT	710 FT	660 FT	665 FT
WIRE SIZE (AWG)	12 AWG	12 AWG	12 AWG	12 AWG
WIRE RESISTANCE (OHMS/1000 FT)	1.98	1.98	1.98	1.98
TOTAL RESISTANCE (OHMS)	2.6334	2.8116	2.6136	2.6334
TOTAL CURRENT (mA)	1.216 A	0.925 A	0.744 A	0.836 A
VOLTS DROPED (VOLTS)	3.2022 V	2.6007 V	1.9445 V	2.2015 V
% VOLTAGE DROP	15.7%	12.75%	9.53%	10.79%
OPERATING VOLTAGE (OPERATING VOLTAGE OF DEVICE IS 16 – 33 VDC)	17.2 V	17.8 V	18.46 V	18.2 V

VOLTAGE DROP FORMULAS: PER NFPA 72, 2010 18.3.2

TOTAL RESISTANCE = (2 * DISTANCE * WIRE RESISTANCE) / 1000

VOLTS DROPPED = CURRENT * TOTAL RESISTANCE

% VOLTAGE DROP = (VOLTS DROPPED / 20.4VDC) * 100

Table 16: Secondary Power Supply Calculation

POWER SUPPLY BATTERY SIZE CALCULATION

	SUPV. CURRENT	ALARM CURRENT
STANDBY TIME 24 HRS.		
ALARM TIME 15 MIN. = 0.250 HRS.		
TOTAL EXTERNAL LOAD (mA)	0 A	3.721 A
ACPS-610: 6 AMP REMOTE POWER SUPPLY	0.13 A	0.13 A
TOTAL EXTERNAL LOAD (AMPS)	0.13 A	3.851 A

CURRENT UNDER ALARM CONDITIONS	
ACPS-610 #3 TOTAL CURRENT = ALARM CURRENT + SUPERVISORY CURRENT	= 3.981 AMPS
HPFF12 #5 TOTAL CURRENT = ALARM CURRENT + SUPERVISORY CURRENT	= 1.781 AMPS
BATTERIES REQUIRED FOR 24 HRS. IN SUPERVISION 15 MIN. IN ALARM	
ACPS-610#3 AH= (STANDBY TIME * SUPERVISORY CURRENT) + (ALARM TIME * ALARM CURRENT)	= 4.08275 AH
HPFF12 #1 AH= (STANDBY TIME * SUPERVISORY CURRENT) + (ALARM TIME * ALARM CURRENT)	= 5.789 AH

9.871750 AH X 1.20 = 11.846 AH REQUIRED (20% DE-RATING FACTOR)

(2) BATTERIES TO BE PROVIDED AT 17AH

The fire alarm system within Building V was correctly designed. The sequence of operations for the system will allow for immediate notification to the local fire department and the occupants of the building. The secondary power supply is also large enough to provide 24 hours of standby power followed by an alarm condition of 15 minutes.

Smoke Control:
Smoke control within Building V is provided by three different methods to limit the spread of smoke within the building. Initiation of the fire alarm system will initiate two methods of smoke control within the building. Upon alarm, all fire rated doors that are on magnetic hold open will release resulting in the doors closing. This action will help keep areas compartmented and maintain the fire rated separation of a room or area. The second condition is through the control of smoke/fire dampers that are installed across fire rated separations. Closing the smoke/fire damper will prevent the HVAC systems from spreading fire and smoke to different areas of the building. Figure 22 shows an image of the smoke/fire dampers installed.

Figure 22: Smoke/Fire Damper

The last method of smoke control is through protection of the hoistway openings. Section 713.14.1 {2013 CBC} requires that all elevators be provided with an elevator lobby. This is because although elevator doors may be fire rated, they are not commonly smoke sealed or gasketed, thus the elevator lobby would prevent smoke from entering the elevator shaft. An exception to this is where a smoke and draft control door assembly tested per UL 1784 is provided. Figure 23 shows the Smokeguard M200 that were installed at the elevator openings. When the smoke detector that is installed within 5’ of the elevator opening is activated, these curtains will release as well as recalling the elevator to the first floor lobby.

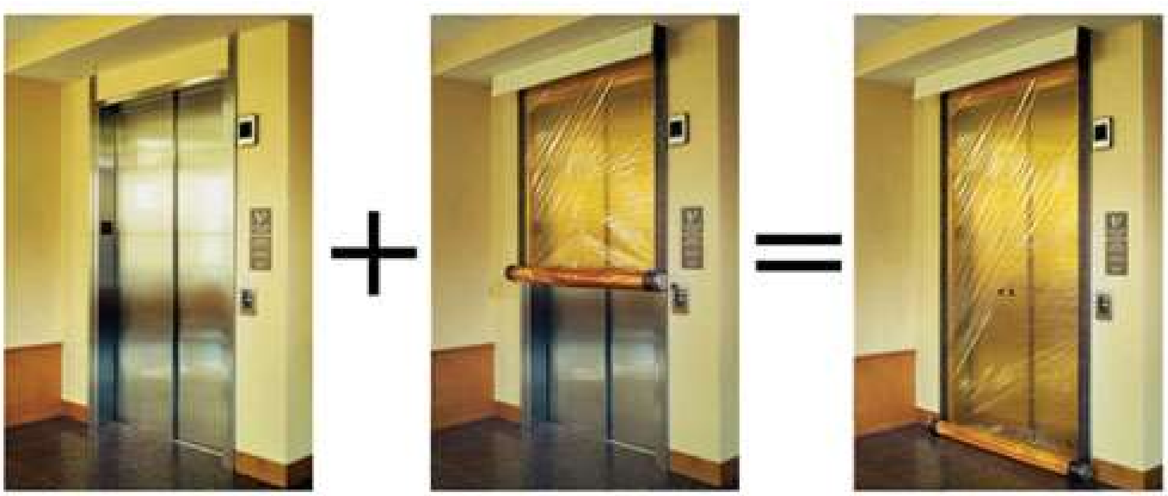


Figure 23: Smokeguard M200

Inspection, Testing, and Maintenance:
The inspection test and maintenance requirements for the fire alarm system and components can be found in Chapter 14 {2013 NFPA 72}. Visual inspection requirements are found in Table 14.3.1 {2013 NFPA 72} and are reproduced in Table 17. Table 17 shows the components that require initial visual acceptance testing and their periodic inspection frequency.

Table 17: Visual Inspection Frequency for Fire Alarm System

Component	Inspection Frequency
1) All equipment	Annual
2) Control equipment:	
a) Fire alarm systems monitored for alarm, supervisory, and trouble signals	
(1) Fuses	Annual
(2) Interfaced equipment	Annual
(3) Lamps and LEDs	Annual
(4) Primary (main) power supply	Annual
4) Supervising station alarm systems-transmitters	
a) Digital alarm communicator-transmitter	Annual
5) In-building fire emergency voice/alarm communications equipment	Semi-Annual
9) Batteries	
b) Nickel-cadmium	Semi-Annual
11) Remote annunciators	Annual
12) Notification appliance circuit power extenders	Annual
13) Remote power supplies	Annual
17) Initiating devices	
b) Duct detectors	
(1) General	Semi-Annual
e) Manual fire alarm boxes	Semi-Annual
i) Smoke detectors	Semi-Annual
l) Waterflow devices	Quarterly
22) Notification appliances	
a) Audible appliances	Semi-Annual
c) Visible appliances	Semi-Annual

Table 18 provides the test requirements found in Table 14.4.3.2 {2013 NFPA 72} and shows the components that require testing and their periodic testing frequency.

Table 18: Testing Frequency for Fire Alarm System

Component	Inspection Frequency
1) All equipment	Refer to Visual Inspection
2) Control equipment:	
a) Functions	
b) Fuses	Annually
c) Interfaced equipment	Annually
d) Lamps and LEDs	Annually
e) Primary (main) power supply	Annually
4) Supervising station alarm systems-transmitters	
a) All equipment	Annually
b) Digital alarm communicator-transmitter	Annually
5) Emergency communications equipment	
a) Amplifier/tone generators	Annually
b) Call-in signal silence	Annually
c) Off-hook indicator (ring down)	Annually
d) Phone jacks	Annually
7) Secondary (standby) power supply	Annually
9) Battery tests	
b) Nickel-cadmium	
(1) Battery replacement	Annually
(2) Charger test	Annually
(3 Discharge test	Annually
(4) Load voltage test	Semi-Annually
11) Remote annunciators	Annually
17) Initiating devices	
e) Manual fire alarm boxes	Annually
i) Smoke detectors – functional test	Semi-Annually
(1) In other than SFD	Annually
22) Alarm notification appliances	
a) Audible textural notification appliances	Annually
c) Visible	Annually

FIRE ALARM SUMMARY

In summary, Building V met all prescriptive requirements for the fire alarm system. The manual fire alarm system with automatic smoke detection and emergency voice/alarm communication system are to code. The location and spacing of initiation and notification devices were approved by the local authority having jurisdiction and found to be compliant with code as well. Appendix A provides complete floor plans for the fire alarm drawings. In order to keep the system operational, the university will need to properly inspect, test, and maintain the system as required. In the next section, the sprinkler system designed per the California Building Code and NFPA 13 will be analyzed.

FIRE SPRINKLER SYSTEM

The California Building Code requires a sprinkler system when certain occupancy groups exceed a given occupant load per the requirements found within section 903 {2013 CBC}. The

California Building Code also requires a standpipe system within the building when a building has exceeded a given height per the requirements found within section 905 {2013 CBC}. This section will take a detailed look into the compliance for the required type of fire sprinkler and standpipe system, sprinkler design criteria, hydraulic calculations, components of the sprinkler system, and inspection, testing, and maintenance of the fire sprinkler system.

Fire Sprinkler Type:
The requirements for a fire sprinkler system need to be verified against each type of occupancy group and the number of occupants. Section 903.2.1.2 {2013 CBC} requires Group A-2 occupancies with an occupant load of over 100 be provided with an automatic sprinkler system. Section 903.2.8 {2013 CBC} also requires all Group R occupancies to be provided with an automatic sprinkler system as well. Additionally, Section 903.2.11.2 {2013 CBC} requires an automatic sprinkler system be provided at the top of rubbish chutes and in their terminal rooms. Chutes shall have additional sprinkler heads be installed at alternate floors and at the lowest intake. Section 903.3.1 {2013 CBC} requires that the design of the sprinkler system must be in accordance with NFPA 13. Section 903.3.2 {2013 CBC} also requires that quick-response or residential sprinklers are to be installed in sleeping units in Group R occupancies.

Standpipe Type:
The requirement to provide a standpipe system within the building is based on the overall height or number of stories of the building. Section 905.3.1 {2013 CBC} requires a Class III standpipe system throughout all floors in a building where the building is four or more stories in height. Class I standpipes are allowed to be used where the building is equipped throughout with an automatic sprinkler system. Per Section 905.4 {2013 CBC} the standpipes are to be located in every required stairway and at the roof. Section 905.2 {2013 CBC} requires that the standpipe system be designed in accordance with NFPA 14.

Fire Sprinkler Design Criteria:
Building V was designed as a wet automatic sprinkler system with a manual wet standpipe system in accordance with NFPA 13 and 14. In a wet system, water is constantly maintained within the piping of the system and water discharges immediately upon activation of a sprinkler head. The water is supplied through a direct connection to the building via a 8” pipe connected to a 12” city water main. A 6” 4-way surface mounted fire department connection is located on the front of the building and is shown in Figure 24 circled in red. The fire hydrant must be located within 100’ of the FDC for building that require a standpipe system. The hydrant is shown in yellow in Figure 24 along with the backflow preventer in blue.

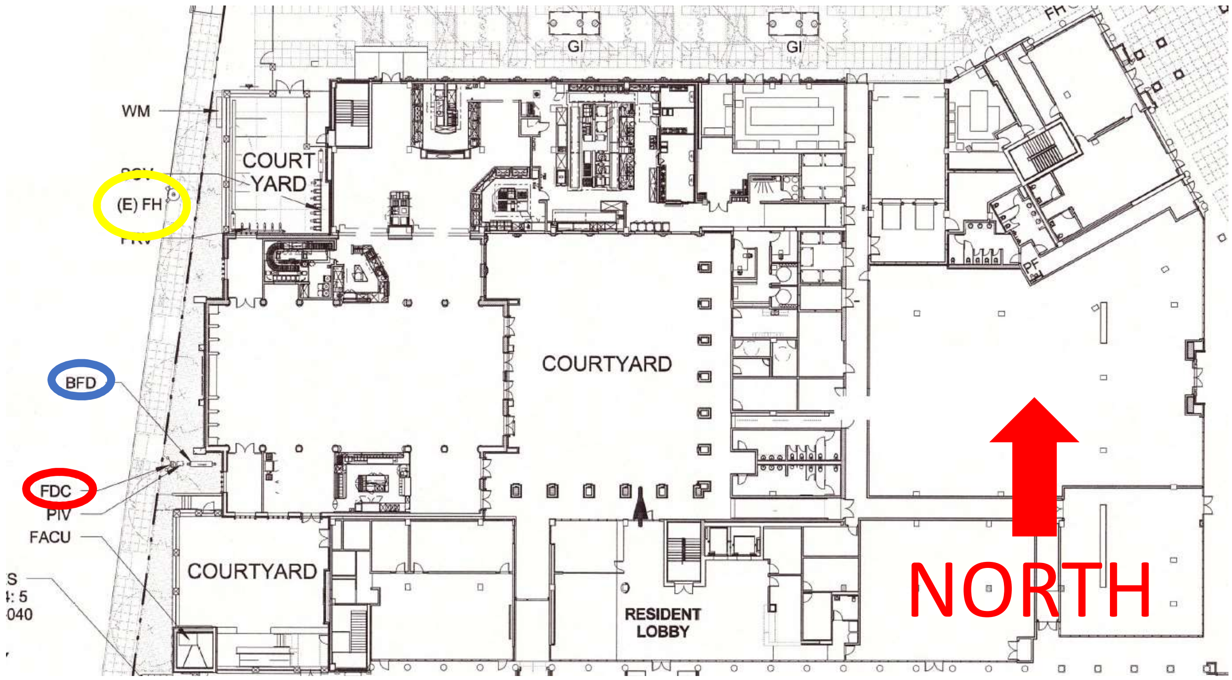


Figure 24: FDC, Fire Hydrant, and Backflow Preventer Location

NFPA 13 provides 5 occupancy hazard classifications for the design of the sprinkler system: Light Hazard, Ordinary Hazard Group I or II, and Extra Hazard Group I or II. The occupancy hazard classification will dictate the required demand the sprinkler system must meet to be effective. Because Building V is mixed use, light hazard and ordinary hazard Group I and II classifications were used depending on the use of the space.

Light Hazard is defined in NFPA 13 "as occupancies or portions of other occupancies where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected." For Building V this would be areas such as lobbies, meeting rooms, seating areas for dining, and the residential dormitories.

Ordinary Hazard Group I is defined in NFPA 13 "as occupancies or portions of other occupancies where combustibility is low, quantity of combustibles is moderate, stockpiles of combustibles do not exceed 8 ft, and fires with moderate rates of heat release are expected. For Building V this would be areas such as storage rooms, dining hall kitchen, electrical rooms.

Ordinary Hazard Group II is defined in NFPA 13 "as occupancies or portions of other occupancies where the quantity and combustibility of contents are moderate to high, stockpiles of contents with moderate rates of heat release do not exceed 12 ft, and stockpiles of contents with high rates of heat release do not exceed 8 ft. For Building V this would be the retail areas.

The amount of water required for the system is shown in Figure 25. The required design density for light hazard is 0.10 gpm/ft^2 over 1,500 ft^2. The required design density for ordinary hazard group I is 0.15 gpm/ft^2 over 1,500 ft^2. The required design density for ordinary hazard group II is 0.20 gpm/ft^2 over 1,500 ft^2.

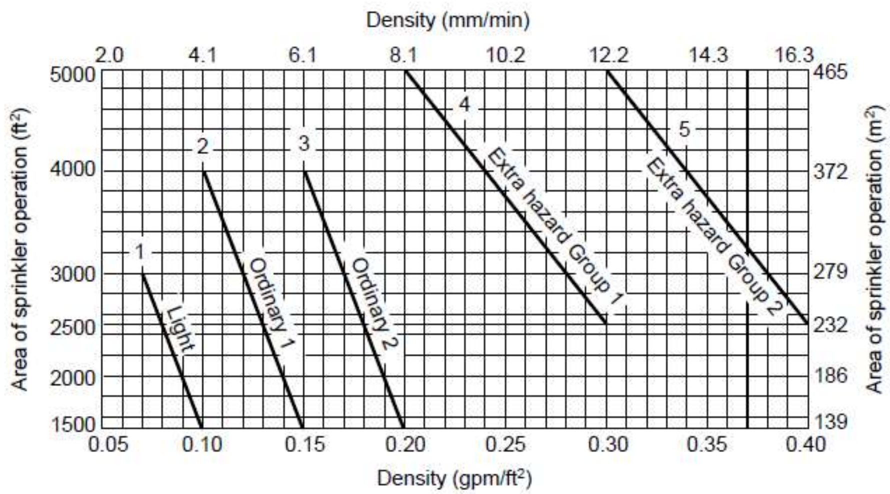


Figure 25: Sprinkler Density/Area Curve

Hydraulic Calculations:
Typically if the city water supply is capable of providing the demands for the sprinkler system, a fire pump is not required within the building. For Building V the fire service pressure flow report shows the available City water supply as:

Static Pressure: 70 psi
Residual Pressure: 65 psi
Residual Flow: 1400 gpm.

Two sample calculation summaries are provided below. The first calculation is for the highest demand on the first floor located within the dining hall. Figure 26 shows the demand and supply curve and that the city supply is above the demand required. Figure 27 shows the location of the most remote sprinklers taken for the calculation. The second calculation is for the highest demand on a residential floor scenario which was taken on the fifth floor. Figure 28 shows the demand and supply curve and that the city supply is above the demand required. Figure 29 shows the location of the most remote sprinklers taken for the calculation.

Level 1 Dining Hall:

Occupancy: Light Hazard
Density: 0.10 gpm/ ft^2
Area of application: 1500 ft^2
Coverage per sprinkler: 225 ft^2 Max
Type of sprinkler: Microfast Quick Response Pendent Sprinkler VK302 (K5.6)
Mirage QR Concealed Pendent Sprinkler VK462 (K5.6)
Hose stream demand: 100 gpm
Total water required: 746.4 gpm @ 59.8 psi

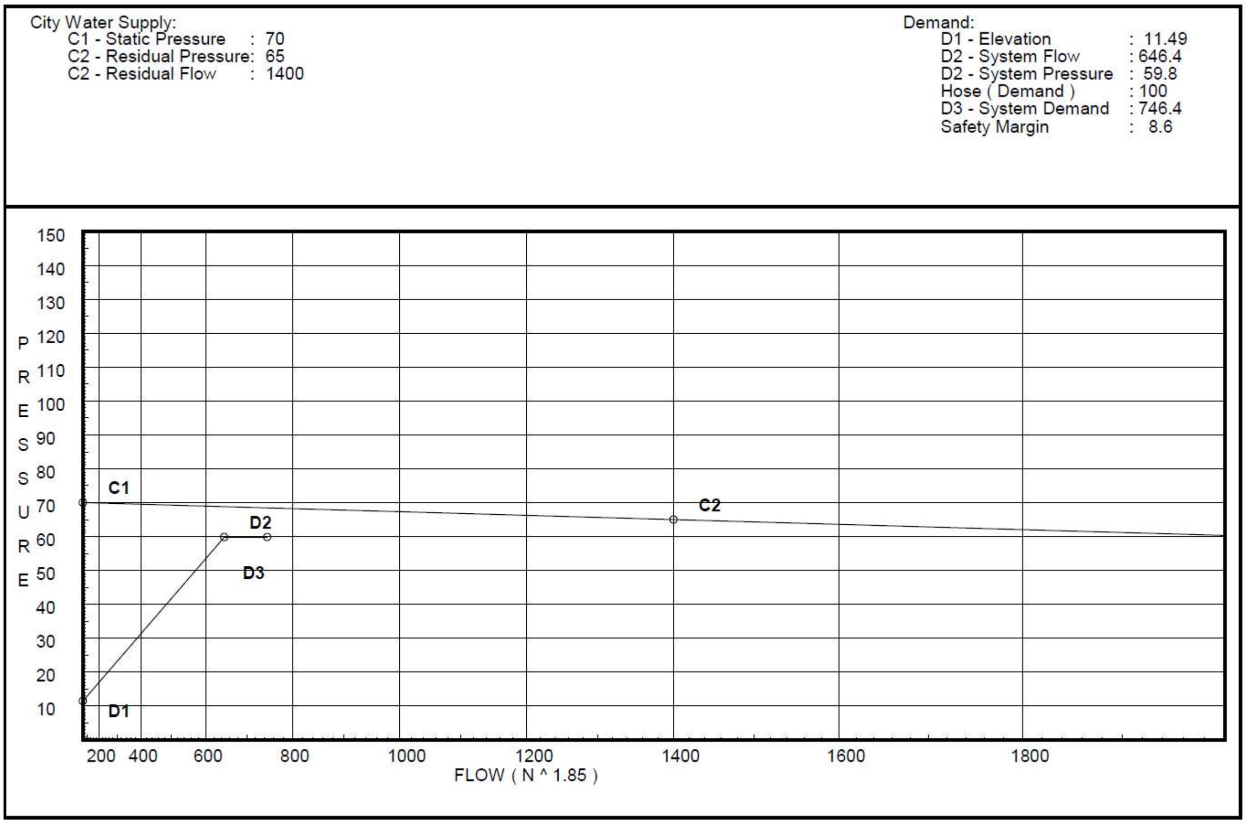


Figure 26: Level 1 Dining Hall Supply and Demand Curve

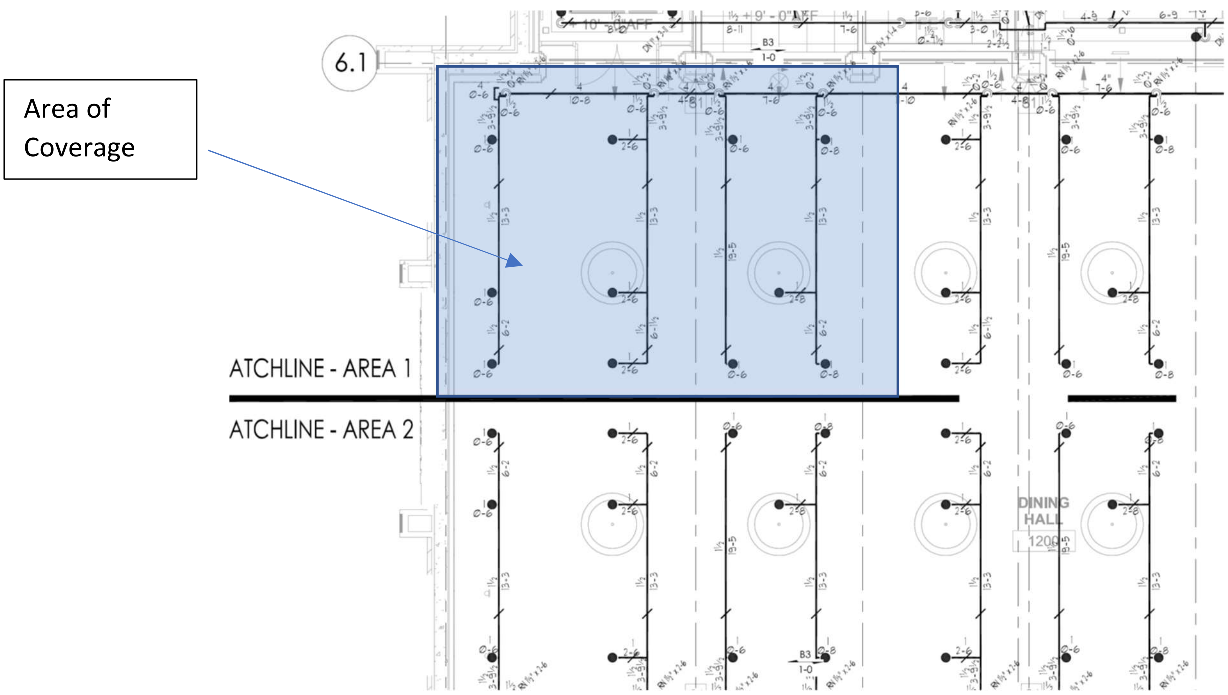


Figure 27: Level 1 Dining Hall Sprinkler Location

Level 5 Dormitory:

Occupancy: Light Hazard
Density: 0.10 gpm/ft^2
Area of application: 4 sprinklers
Coverage per sprinkler: Varies
Type of sprinkler: Freedom Residential Horizontal Sidewall Sprinkler VK460 (K5.8)
Freedom Residential Concealed Pendent Sprinkler VK474 (K5.8)
Hose stream demand: 100 gpm
Total water required: 196.1 gpm @ 66.2 psi

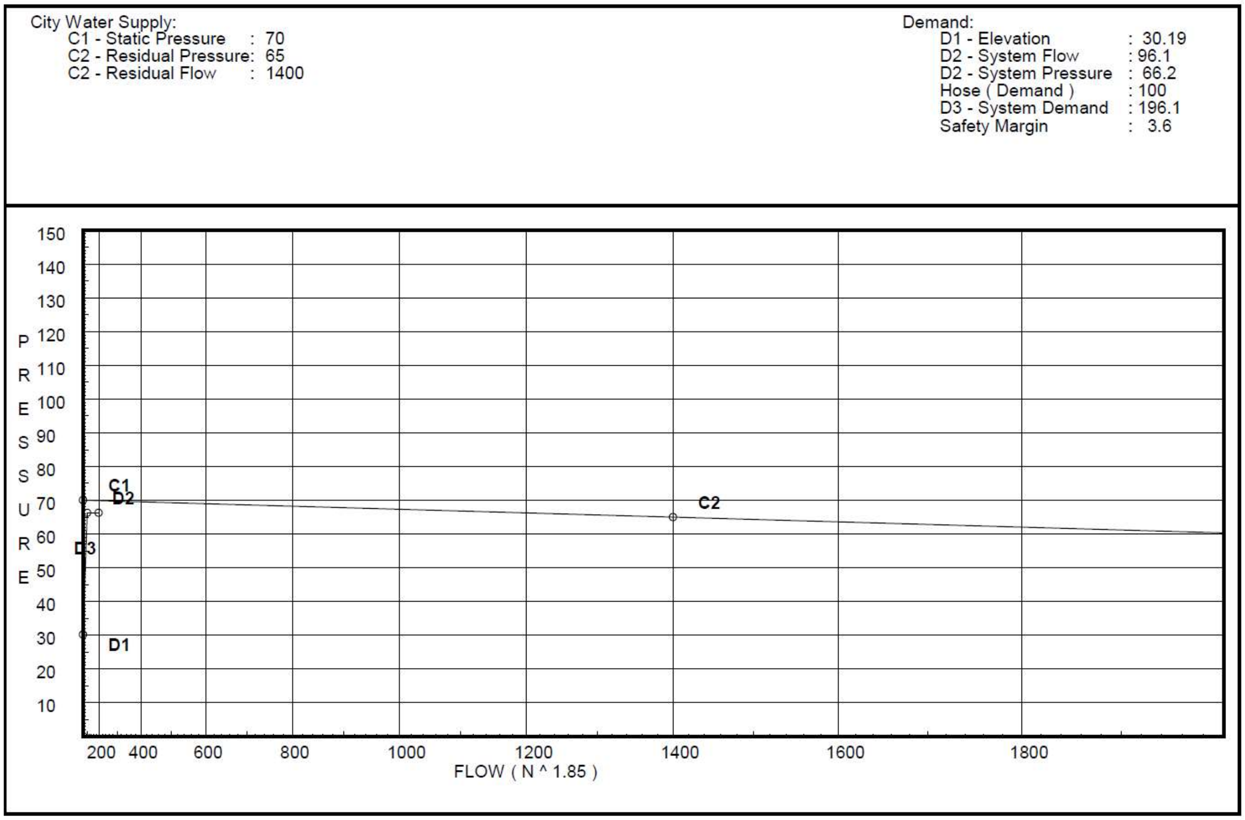


Figure 28: Level 5 Dormitory Supply and Demand Curve

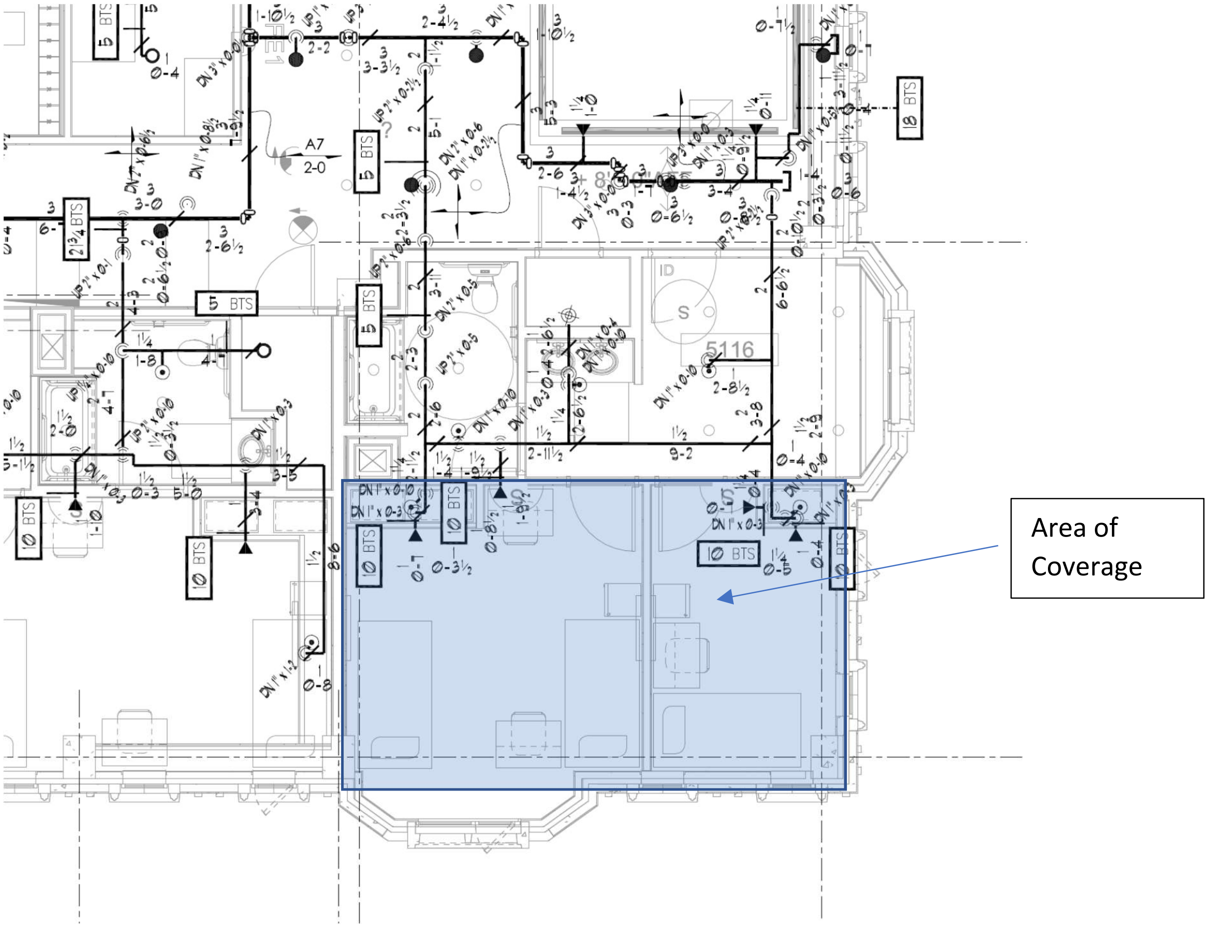


Figure 29: Level 5 Residential Floor Sprinkler Location

Figures 26 and 28 show that the required amount of waterflow and pressure can be supplied by the city water supply and a fire pump would not be required. Additionally, the standpipe pressure demand of 100 psi at the highest roof outlet is able to be supplemented by the local fire department engines (As approved by the local AHJ).

Sprinkler Components:
The level 1 areas are installed with Microfast Quick Response Pendent Sprinkler VK302 (K5.6), Microfast Quick Response Upright Sprinkler VK300 (K5.6), or Mirage QR Concealed Pendent Sprinkler VK462 (K5.6) on branch lines ranging from 1”-1.5”. These branch lines are connected to 4” cross mains which are connected to the 6” riser within the stairwells. Figures 30-32 show the typical fire sprinklers used on Level 1 of Building V.

Figure 30: Microfast Quick Response Pendent Sprinkler VK302

Figure 31: Microfast Quick Response Upright Sprinkler VK300

Figure 32: Mirage QR Concealed Pendent Sprinkler VK462

The residential floor levels are installed with Freedom Residential Horizontal Sidewall Sprinkler VK460 (K5.8) or Freedom Residential Concealed Pendent Sprinkler VK474 (K5.8) on branch lines ranging from 1”-2.5”. These branch lines are connected to 4” cross mains which are connected to the 6” riser within the stairwells. Figures 33-34 show the typical fire sprinklers used on Level 1 of Building V.

Figure 33: Freedom Residential Horizontal Sidewall Sprinkler VK460

Figure 34: Freedom Residential Concealed Pendent Sprinkler VK474

Inspection, Testing, and Maintenance:
The inspection test and maintenance requirements for the fire sprinkler system can be found in Table 5.1.1.2 {2013 NFPA 25}. Table 19 shows the inspection, testing, and maintenance schedule.

Table 19: Fire Sprinkler Inspection, Testing, and Maintenance

Item	Frequency
INSPECTION	
Control valves	Quarterly
Waterflow alarm devices	Quarterly
Valve supervisory alarm devices	Quarterly
Supervisory signal devices	Quarterly
Gauges	Quarterly
Hydraulic nameplate	Quarterly
Hanger/seismic bracing	Annually
Pipe and fittings	Annually
Sprinklers	Annually
Spare sprinklers	Quarterly
Information Sign	Annually
TESTING	
Waterflow alarm devices	Annually
Valves supervisory alarm devices	Annually
Supervisory signal devices	Annually
Gauges	5 years
Sprinklers	At 50 years and every 10 years after
MAINTENANCE	
Valves	Annually
Sprinklers and automatic spray nozzles protecting commercial cooking equipment	Annually

FIRE SPRINKLER SUMMARY
In summary, Building V met all prescriptive requirements for the fire sprinkler system. The location and spacing of sprinkler heads as well as the demand at the most remote points will be able to control a fire in these areas based on the uses. Appendix B provides complete floor plans for the fire sprinkler drawings. In order to keep the system operational, the university will need to properly inspect, test, and maintain the system as required. In the next section, compliance for means of egress designed per the California Building Code will be discussed.

MEANS OF EGRESS
The 2013 California Building Code requires that all buildings be provided with exits that are sized to the occupant load in quantity and capacity and arranged in a manner that complies with the requirements found in Chapter 10. The three basic components of the means of egress are: 1) Exit Access, 2) Exit, and 3) Exit Discharge. Each component progressively increases safety as occupants are directed from an occupied space to outside the building. This section will detail compliance for the means of egress by calculating the occupant load and then break down the three elements of egress: exit access, exit, and the exit discharge.

Occupant Load:
Occupant loads in Chapter 10 of the California Building Code are calculated based on the function of each space. An occupant load factor is assigned to each space and is used to

calculate the occupant load by dividing the floor area by the occupant load factor. Table 20 lists all the applicable occupant load factors used in Building V, found in Table 1004.1.2 {2013 CBC}. (It should be noted that although dormitories are listed as 1 occupant per 50 SF of area, the university applied for a request to base the occupant load on 1 occupant per 200 SF given that the honors housing would only have 1 occupant per bedroom).

Table 20: Maximum Floor Area per Occupant

Function of Space	Occupant Load Factor
Storage Areas/Mechanical Equipment Room	300 gross
Assembly without fixed seats Table and Chairs	 15 net
Business areas	100 gross
Kitchens, commercial	200 gross
Mercantile Grade floor areas Storage, stock	 30 gross 300 gross
Residential	200 gross

Table 21 shows the occupant load breakdown for each space for Level 1. Figure 35 provides the Level 1 floor plan showing the areas where the occupant loads were taken.

Table 21: Level 1 Occupant Load Calculation

AREA SCHEDULE (LEVEL 1)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
	COVERED AREA	A-3	2,882 SF	15	193
	CORRIDOR	B	2,948 SF	200	15
	CORRIDOR	R-2	177 SF	200	1
1000	RES. LOBBY	B	2,520 SF	100	26
1001	CUSTOMER SERV.	B	258 SF	100	3
1001A	HOUSING OFFICE	B	175 SF	100	2
1001B	OFFICE	B	216 SF	100	3
1001C	ELECT.RM.	S-2	207 SF	300	1
1001D	RES. ED OFFICE	B	211 SF	100	3
1001E	RESTROOM	B	85 SF	200	1
1002	LOUNGE	B	427 SF	15	29
1100	RECREATION	A-3	1,459 SF	15	98
1100A	SMALL GROUP	A-3	245 SF	15	17
1100B	SMALL GROUP	A-3	653 SF	15	44
1100C	STORAGE	S-2	111 SF	300	1
1180	RESTROOM	B	70 SF	200	1
1181	RESTROOM	B	70 SF	200	1
1183	FIRE RISER2	S-2	40 SF	200	1
1200	DINING HALL	A-2	8,513 SF	15	568
1200A	SALAD/DELI/SOUP	B	510 SF	200	17
1200B	PRIVATE DINING ROOM	A-2	227 SF	15	16
1200C	PRIVATE DINING ROOM	A-2	234 SF	15	16
1200E	DISH WASHING	B	700 SF	100	7
1250	SALAD/DELI/SOUP	B	552 SF	200	3
1250	VEGAN	B	485 SF	200	3
1300	KITCHEN	B	3,141 SF	200	16
1300G	STORAGE	S-2	475 SF	300	2
1330E	OFFICE	B	582 SF	100	6
1332	BREAK RM.	B	221 SF	15	3
1332A	CHANGE	S-2	86 SF	100	1
1332B	CHANGE	S-2	113 SF	100	2
1340	LOADING DOCK	S-2	510 SF	300	2
1340	LOADING PARKING	S-2	1,020 SF	300	4
1341	TRASH	S-2	253 SF	300	1
1342	CHEM ROOM	B	54 SF	100	1
1343	TRASH	S-2	288 SF	300	1
1344	RECYCLING	S-2	136 SF	300	1
1345	STORAGE	S-2	345 SF	300	2
1348	HALLWAY	B	1,933 SF	200	10
1349	CART WASH	B	98 SF	100	1
1380	ELECTRICAL	S-2	212 SF	300	1
1381	JANITOR	S-2	90 SF	200	1
1382	IDF	S-2	244 SF	300	1
1383	RESTROOM	B	407 SF	200	2
1384	RESTROOM	B	412 SF	200	3
1388	IDF	S-2	172 SF	300	1
1390	ELECTRICAL	S-2	811 SF	300	3
1400A	GENERAL RETAIL	M	8,667 SF	30	289
1400B	FOOD AND BEVERAGE	A-2	2,298 SF	15	154
1480	HALLWAY	B	485 SF	200	
1481	RESTROOM	B	305 SF	200	2
1482	RESTROOM	B	286 SF	200	2
1500	LOUNGE	A-3	949 SF	15	64
1500A	RESTROOM	B	77 SF	200	1
1500B	RESTROOM	B	89 SF	200	1
1501	RECREATION	A-3	880 SF	15	59
1502	STORAGE	S-2	168 SF	300	1
1590	ELECTRICAL	S-2	669 SF	300	3
1591	UTILITY	S-2	335 SF	300	1
1600	BIKE STORAGE	S-2	2,752 SF	300	10
60			53,536 SF		1722

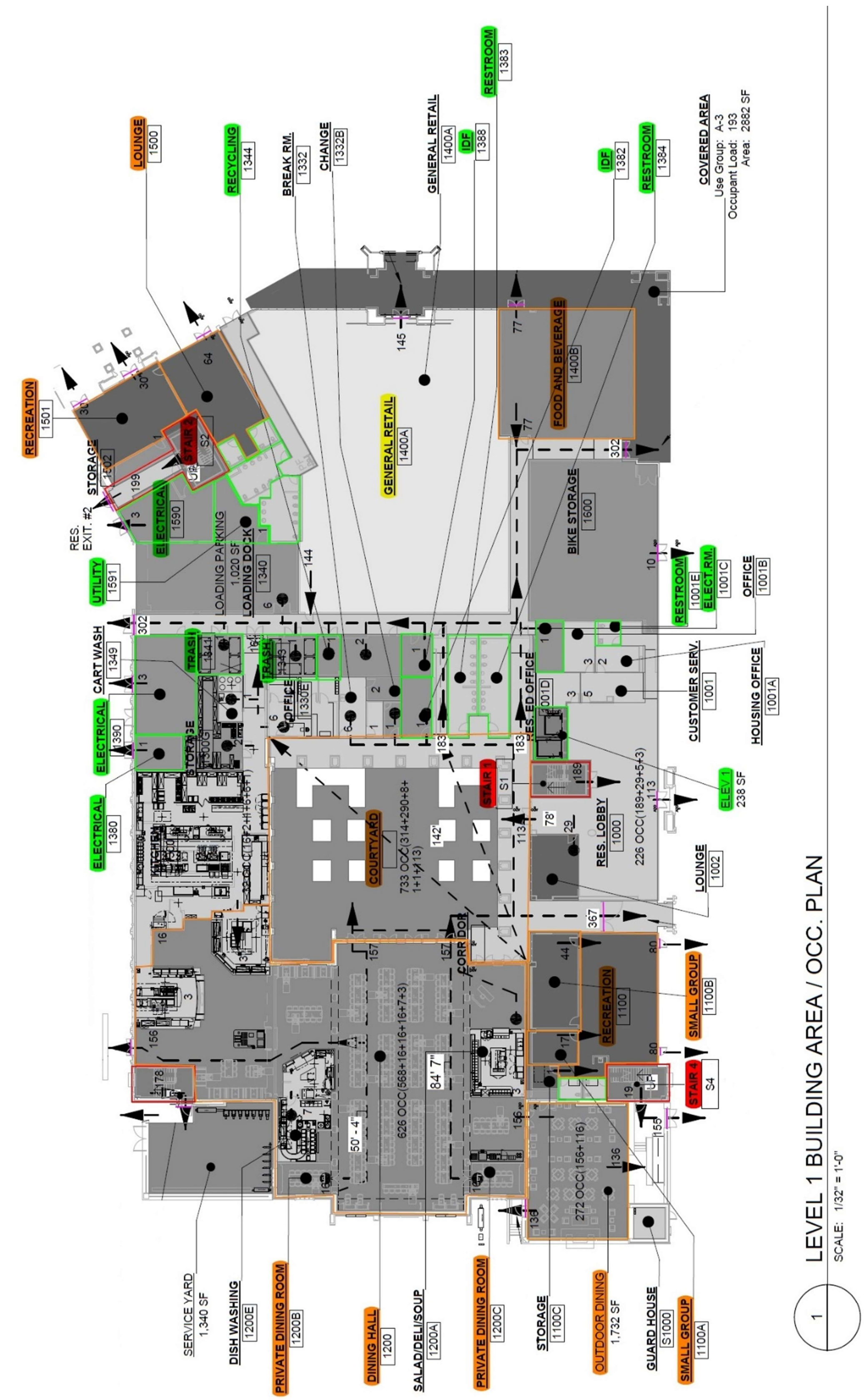


Figure 35: Level 1 Occupant Load Floor Plan

Table 22 shows the occupant load breakdown for each space for Level 2 broken up into 4 zones. Figure 36 provides the Level 2 floor plan showing the areas where the occupant loads were taken. Appendix C provides complete floor plans for the occupant load calculations.

Table 22: Level 2 Occupant Load Calculation

AREA SCHEDULE (LEVEL 2, ZONE 3)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2380	JANITOR	B	106 SF	100	1
2382	TRASH	B	87 SF	100	1
2205 - Type H	RES. UNITS	R-2	820 SF	200	5
2206 - Type F	RES. UNITS	R-2	589 SF	200	3
2301 - Type M3	RES. UNITS	R-2	1,291 SF	200	7
2302 - Type M2	RES. UNITS	R-2	1,317 SF	200	7
2305 - Type H	RES. UNITS	R-2	775 SF	200	4
2306 - Type E	RES. UNITS	R-2	516 SF	200	3
2307 - Type E	RES. UNITS	R-2	516 SF	200	3
2308 - Type E	RES. UNITS	R-2	516 SF	200	3
2309 - Type E	RES. UNITS	R-2	517 SF	200	3
2310	RES. LIFE	R-2	258 SF	15	18
2311 - Type E	RES. UNITS	R-2	516 SF	200	3
2312 - Type E1	RES. UNITS	R-2	515 SF	200	3
2314 - Type L1	RES. UNITS	R-2	965 SF	200	5
CORRIDOR (Zone3)	CORRIDOR (Zone3)	R-2	1,781 SF	200	8
2381	IDF	S-2	111 SF	300	1
2383	ELECTRICAL	S-2	244 SF	300	1
18			11,442 SF		79

AREA SCHEDULE (LEVEL 2, ZONE 1)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
	CORRIDOR (Zone1)	R-2	2,574 SF	200	12
2101 - Type H	RES. UNITS	R-2	772 SF	200	4
2108 - Type E	RES. UNITS	R-2	516 SF	200	3
2109 - Type E	RES. UNITS	R-2	536 SF	200	3
2110 - Type E_ACC	RES. UNITS	R-2	516 SF	200	3
2111	RES. LIFE	R-2	258 SF	15	18
2112 - Type H_ACC	RES. UNITS	R-2	775 SF	200	4
2114 - Type C	RES. UNITS	R-2	517 SF	200	3
2114 - Type C	RES. UNITS	R-2	536 SF	200	3
2115 - Type H	RES. UNITS	R-2	775 SF	200	4
2116 - Type E3	RES. UNITS	R-2	594 SF	200	3
2118 - Type E	RES. UNITS	R-2	524 SF	200	3
2119 - Type C	RES. UNITS	R-2	518 SF	200	3
2122 - Type F	RES. UNITS	R-2	594 SF	200	3
2124 - Type H	RES. UNITS	R-2	788 SF	200	4
2125 - Type C	RES. UNITS	R-2	524 SF	200	3
2126 - Type C	RES. UNITS	R-2	527 SF	200	3
2201 - Type H	RES. UNITS	R-2	820 SF	200	5
2202 - Type F	RES. UNITS	R-2	591 SF	200	3
2180	IDF	S-2	158 SF	300	1
2181	ELECTRICAL	S-2	109 SF	300	1
2182	ELECTRICAL	S-2	150 SF	300	1
22			13,671 SF		90

AREA SCHEDULE (LEVEL 2, ZONE 4)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2102 - Type H	RES. UNITS	R-2	775 SF	200	4
2103 - Type H	RES. UNITS	R-2	800 SF	200	5
2106 - Type C	RES. UNITS	R-2	775 SF	200	4
2107 - Type H	RES. UNITS	R-2	516 SF	200	3
CORRIDOR (Zone4)	CORRIDOR (Zone4)	R-2	447 SF	200	3
5			3,313 SF		19

COURTYARD - COVERED SPACE / A-3 / 1,149 SF / 15 / 77

AREA SCHEDULE (LEVEL 2, ZONE 2)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2413	LAUNDRY	B	440 SF	100	4
2121	RES. LIFE	R-2	558 SF	15	37
2401 - Type M1	RES. UNITS	R-2	1,285 SF	200	6
2404	RES. LIFE	R-2	515 SF	15	34
2406 - Type E	RES. UNITS	R-2	517 SF	200	3
2407 - Type C	RES. UNITS	R-2	516 SF	200	3
2408 - Type H3	RES. UNITS	R-2	667 SF	200	3
2411 - Type E2	RES. UNITS	R-2	569 SF	200	3
CORRIDOR (Zone2)	CORRIDOR (Zone2)	R-2	1,159 SF	200	6
9			6,227 SF		99

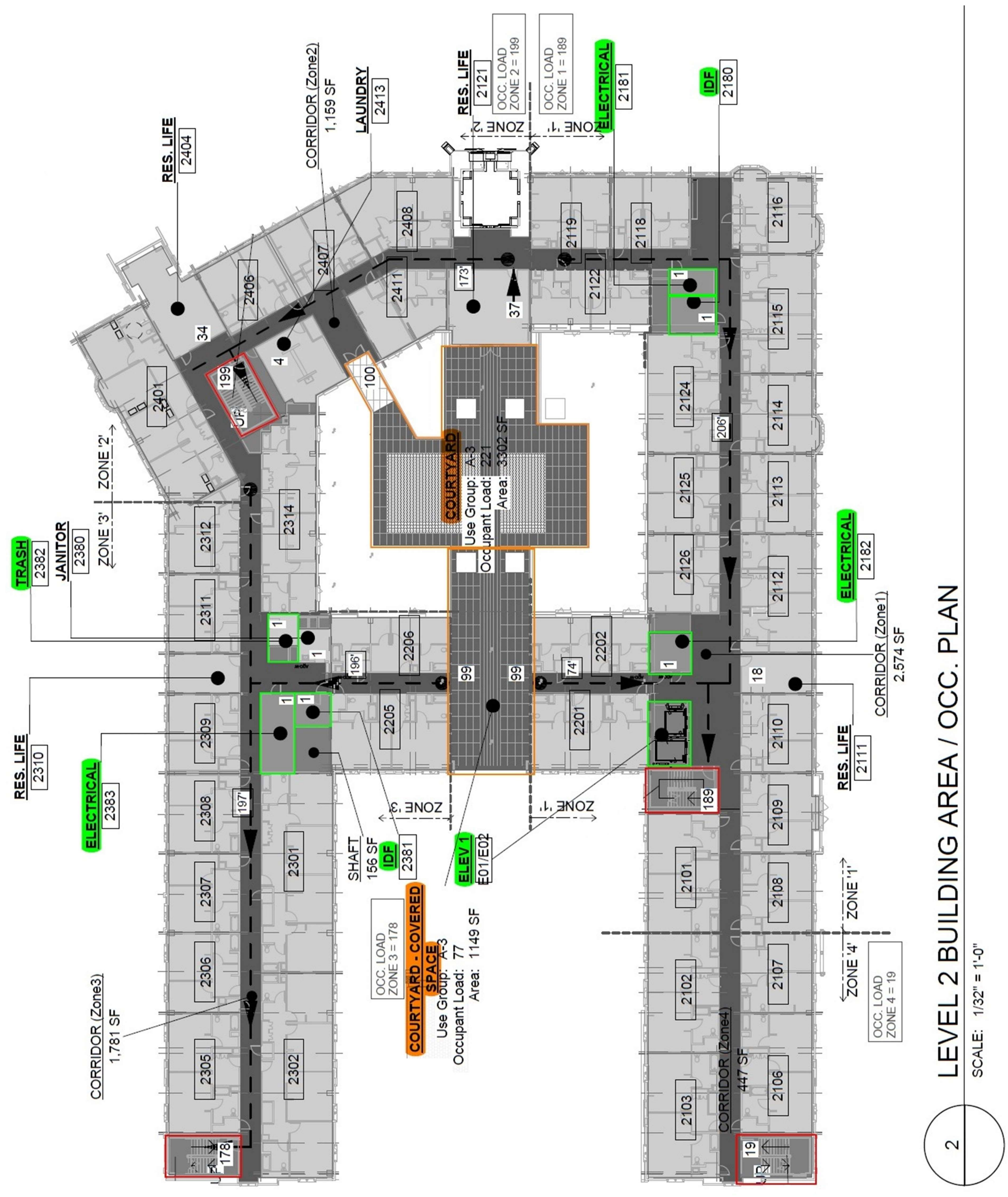


Figure 36: Level 2 Occupant Load Floor Plan

Exit Access:
Once the occupant load has been established, the number of exit access doors, common path of egress, spacing of doors, the width of the exit access and doors, dead ends, and exit signage must be arranged properly to allow for safe egress of the building occupants. All spaces are required to have two exits or exit access doors at a minimum unless the values found in Table 1015.1 {2013 CBC} are not exceeded. Spaces with 501-1,000 occupants require three exits or

exit access doorways and spaces greater than 1,000 occupants require four. Table 23 lists the requirements for spaces to only have one exit. Except for the courtyards, dining hall, retail space, and large meeting rooms on Level 1, all of the remaining spaces are allowed to have one exit or exit access doorway.

Table 23: Spaces with One Exit or Exit Access Doorway

Occupancy	Maximum Occupant Load
A, B, M	49
R	10
S	29

Another limitation where the code may require additional exit or exit access doors are if the common path of egress travel is exceeded. Table 1014.4 {2013 CBC} requires that occupants cannot travel more than a certain distance before a choice of two exits or exit access doors are available to them. Additionally, Section 1028.8 {2013 CBC} requires assembly uses with seating with an occupant load of 50 or more to be limited to 30’ for common path. Table 24 lists the maximum common path of egress allowed. Figures 36 and 37 show the worst case scenarios for the common path of egress being under the allowable distances.

Table 24: Common Path of Egress Travel

Occupancy	Common Path (ft)
B, S	100
R-2	125
A, M	75
A with seating (> 49 occupants)	30

Once the number of required exit access doorways have been determined, when two or more doors are required, there is a requirement for the separation of the doors. This requirement is so that if for some reason one of the doors are unable to be used, like in the case of a fire adjacent to the door, the other door will still be available for egress. Section 1015.2 {2013 CBC} requires that doorways be separated by one-third the diagonal of the space in buildings that are sprinklered.

The width of the exit access and doors are also important because higher occupant loads will require larger widths so that occupants can quickly and safely egress without creating bottlenecks. Section 1005.3.2 {2013 CBC} states that all egress components, other than stairs, require 0.2” of egress width per occupant. This can be reduced to 0.15” per occupant if the building is fully sprinklered and provided with an emergency voice/alarm communication system. Corridors are required to be a minimum of 44” wide per Table 1018.2 {2013 CBC}, unless the corridor serves less than 50 occupants where the width can be reduced to 36”. The minimum size of doors is regulated by Section 1008.1.1 {2013 CBC} which requires 32” of clear width.

The final component for exit access is the limitation on dead ends. Section 1018.4 {2013 CBC} requires that dead ends be limited to 50’ in sprinklered buildings and 20’ for assembly use occupants. This requirement is so that occupants do not have to travel too far before having to turn around because the path they have gone down does not lead to an exit. There were no dead ends greater than 20’ on any of the floors.

In order to provide proper wayfinding for occupants, exit signage must be provided when a space requires two or more exits or exit access doors. Section 1011.1 {2013 CBC} requires that exits and exit access doorways be marked with an approved exit sign readily visible from any direction of egress. These exit signs must also be placed so that the nearest visible sign is within 100’. The exit signs are required to be internally or externally illuminated at all times and connected to an emergency power supply to remain illuminated for not less than 90 minutes in the case of power loss to the building.

Exits:
Exits are designed to be the next level of safety after the exit access. Similar to exit access doorways, the California Building Code requires a minimum of two exits per story unless unless the values found in Table 1021.2(2) {2013 CBC} are not exceeded. Building V provides a minimum of two exits at all times from every story and does not utilize Table 1021.2(2).

Once occupants have begun to travel along the exit access system, the code has specific requirements on the location and sizing of exits. Table 1016.2 {2013 CBC} lists the maximum exit access travel distance occupants are allowed to travel based on the occupancy group before reaching an exit. This requirement is so that occupants do not have to travel too far based on the assumed hazards for the types of occupancies. Table 25 lists the maximum exit access travel distance. Figures 37 and 38 show the worst case scenario for the exit access travel distance being less than the allowable.

Table 25: Exit Access Travel Distance

Occupancy	Exit Access Travel Distance (ft)
A, M, R	250
B	300
S-2	400

Exit stairs also have a separate requirement for sizing similar to doors. Section 1005.3.1 {2013 CBC} states that all stairs require 0.3” of egress width per occupant. This can be reduced to 0.2” per occupant if the building is fully sprinklered and provided with an emergency voice/alarm communication system. Stairs must be a minimum of 44” wide per Section 1009.4 {2013 CBC} unless the stair serves less than 50 occupants where the width can be reduced to 36”. Figures 37 and 38 show the required and provided exit door and stair sizing.

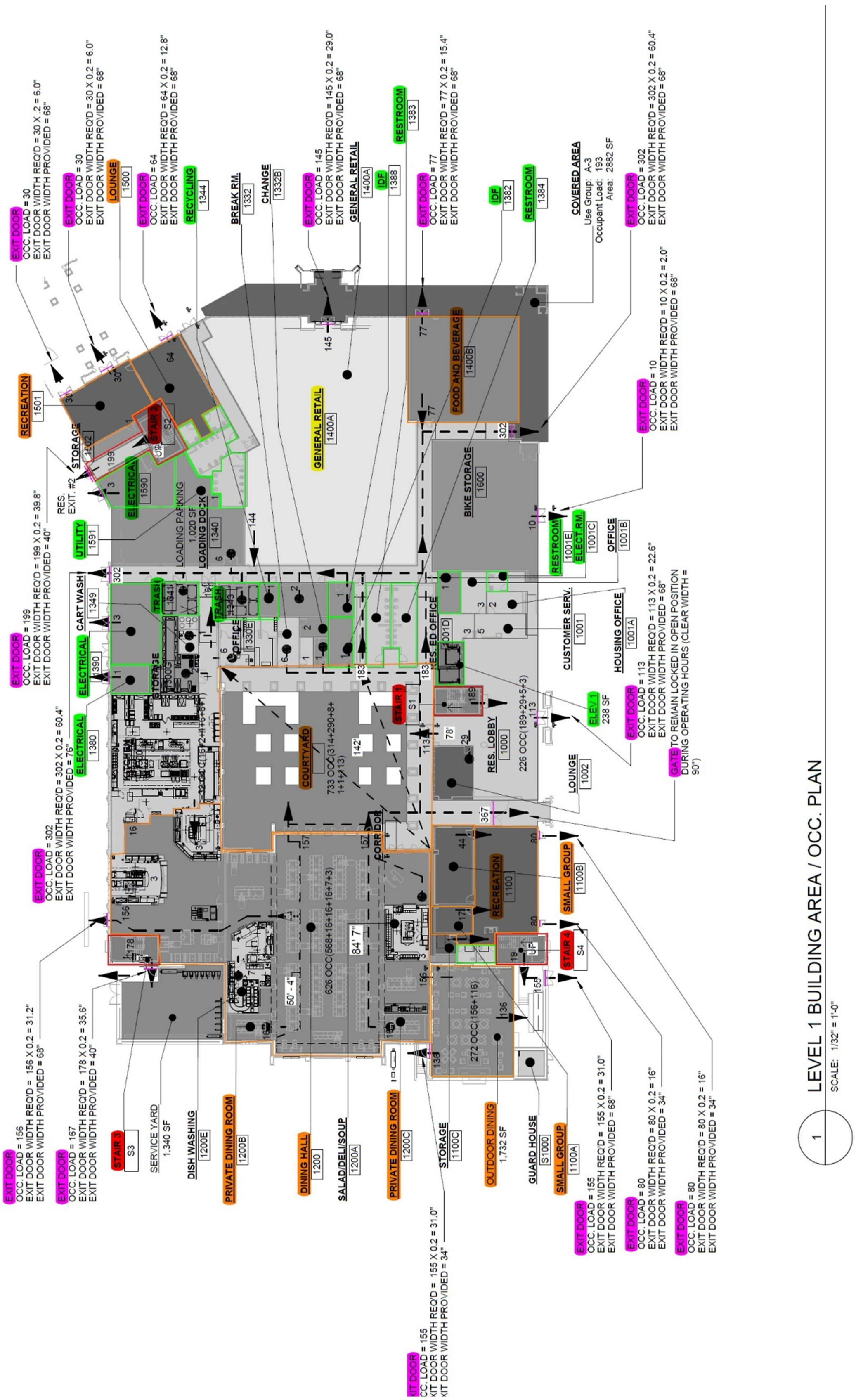


Figure 37: Level 1 Exit Door Sizing

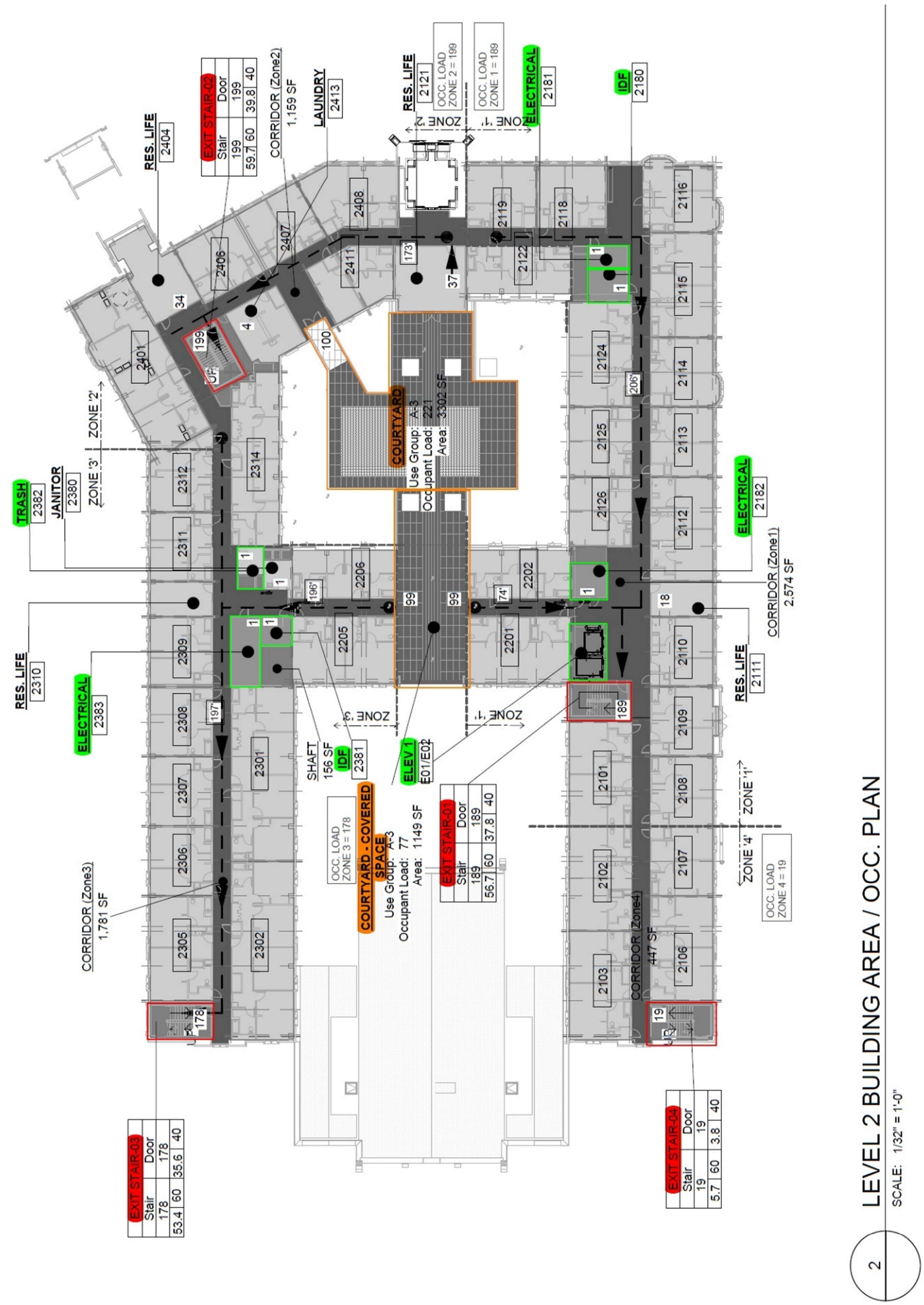


Figure 38: Level 2 Exit Door/Stair Sizing

Exit Discharge:
Once the occupants have entered the exit, they must leave the exit safely. Section 1027 {2013 CBC} provides requirements on the discharge of exits. The exits must discharge directly to the exterior of the building at grade without reentering the building and provide a direct and unobstructed access to a public way. The exit discharge must also be sized in accordance with the size of the exit enter the exit discharge. All the exits for Building V discharge to the exterior and provide a direct path to the public way.

MEANS OF EGRESS SUMMARY
In summary, Building V met all prescriptive requirements for the means of egress. All spaces and stories were provided with the correct number of exits or exit access doorways. The exits and exit access doorways were properly located so that exit access travel distance did not exceed the allowable per code and were properly separated. All doors and stairs were properly sized for the occupant load they were serving. And lastly, occupants were able to discharge safely to the public right of way.

PRESCRIPTIVE DESIGN SUMMARY
Building V met all prescriptive requirements per the 2013 California Building Code. The building was required to go through plan check with the Authority Having Jurisdiction and obtained all required permits for construction. The construction was properly inspected, and a certificate of occupancy was provided allowing the building to be occupied. In the next section a theoretical performance based design approach to see if the building would be able to provide tenable conditions for safe egress in the event of a fire.

PERFORMANCE BASED DESIGN

A performance-based design is another approach to design a building for occupant life safety by determining if a set of performance goals can be met through the building design. Multiple design fire scenarios are considered with a worst-case design fire selected to see if the goals and objectives determined by the multiple stakeholders can be achieved.

Based on Section 4.1.1 {2015 NFPA 101} a goal of life safety "is to provide an environment for the occupants that is reasonably safe from fire by the following means:
(1) Protection of occupants not intimate with the initial fire development
(2) Improvement of the survivability of occupants intimate with the initial fire development."

The overall goal for this performance evaluation is to determine if the available safe egress time (ASET) was greater than the required safe egress time (RSET) for the building occupants. Various design fire scenarios were considered and one was selected as the worst case design fire. The selected design fire had to be characterized as inputs so that the fire could be modeled using Pyrosim. Tenability conditions were also determined based on previous research. Using the Pyrosim simulated data, the time to reach these untenable conditions were found. Lastly, the required time for occupants to safely egress the floor was modeled and simulated using Pathfinder. This report will detail the steps that were taken to determine if ASET was greater than RSET.

Design Fire Scenarios:
Design fire scenarios are used to define how the fire develops and how the combustion products spread throughout the building and the effects of the combustion products to the occupants of the building. For this analysis, the design fires were developed to define the conditions that occupants of the dormitory are expected to experience. The fire scenarios take into account the fire safety systems that are installed to help mitigate the effects of the fire, such as the egress system, automatic smoke detection, automatic sprinkler suppression, and passive fire partitions.

Eight fire scenarios described in Section 5.5.3 {2015 NFPA 101} were considered:

1. Design Fire Scenario 1: An occupancy-specific fire representative of a typical fire for the occupancy based on occupant activities.
2. Design Fire Scenario 2: An ultrafast-developing fire, in the primary means of egress, with interior doors open at the start of the fire.
3. Design Fire Scenario 3: A fire that starts in a normally unoccupied room, potentially endangering a large number of occupants in a large room or other area.
4. Design Fire Scenario 4: A fire that originates in a concealed wall or ceiling space adjacent to a large occupied room.
5. Design Fire Scenario 5: A slowly developing fire, shielded from fire protection systems, in close proximity to a high occupancy area.
6. Design Fire Scenario 6: The most severe fire resulting from the largest possible fuel load characteristic of the normal operation of the building.
7. Design Fire Scenario 7: An outside exposure fire.
8. Design Fire Scenario 8: A fire originating in ordinary combustibles in a room or area with each passive or active fire protection system independently rendered ineffective.

Based on these eight generic scenarios, a few sample fire scenarios were drafted for consideration.

Scenario 1: A fire originates in a concealed space or unoccupied storage room spreading to the adjacent dining hall. This scenario was eliminated because a fire in a storage room would be expected to be easily controlled by sprinklers. Furthermore, the dining hall has a 40' high ceiling volume which would assist in minimizing tenability concerns for the occupants.

Scenario 2: The couch located within the rated corridor catches on fire causing the fire to spread throughout the floor corridor system. The growth of the fire would be controlled by activation of the automatic sprinkler system. This scenario was selected due to the location of the fire and the challenge it would create to occupant tenability.

Scenario 3: A fire in a dormitory room with the sprinklers rendered ineffective. This scenario was eliminated due to the redundancy in protection systems that are provided within the building. All the dormitory rooms are required to have 20-min fire rated and smoke gasketed doors which would provide a barrier to protect the means of egress. The rooms and corridors also have automatic smoke detection which would allow for early occupant notification.

Design Fire Characterization:
Design fires are created as a means of quantifying the fire scenarios as inputs into the fire modeling analysis. The fuel load, heat release rate (HRR), heat of combustion, soot yield, and carbon monoxide yield must be identified for modeling. In the design fire scenario, a standard 3'x6' couch as the fuel load was assumed. The material composition of the couch is unknown, so for the basis of this report a mixture of 70% cellulose material and 30% expanded flexible polyurethane was assumed.

Physical tests were conducted in 1982 to obtain heat release rates of upholstered furniture.[1] From the test of 13 chairs, sample F32 most closely resembles the couch in Building V. F32 was a sofa comprised of a wood frame using California Foam (polyurethane foam meeting California State Bulletin 117). Figure 39 shows a graph of the heat release rate vs time. From the test data, F32 reached a peak heat release rate of 3120 kW in a time of 250 seconds.

Design fires are typically characterized by a "t-squared" exponential growth rate. The following equation is used to estimate the heat release rate for a t-squared fire:

$q = \alpha * t^2$
where: α = 0.18 (ultra-fast) / 0.047 (fast) / 0.012 (medium)
t = time (sec)

Based on the recorded data from F32, for a peak heat release rate of 3120 kW in 250 seconds, alpha would equal 0.049 which most closely resembles a "fast" t-squared fire.

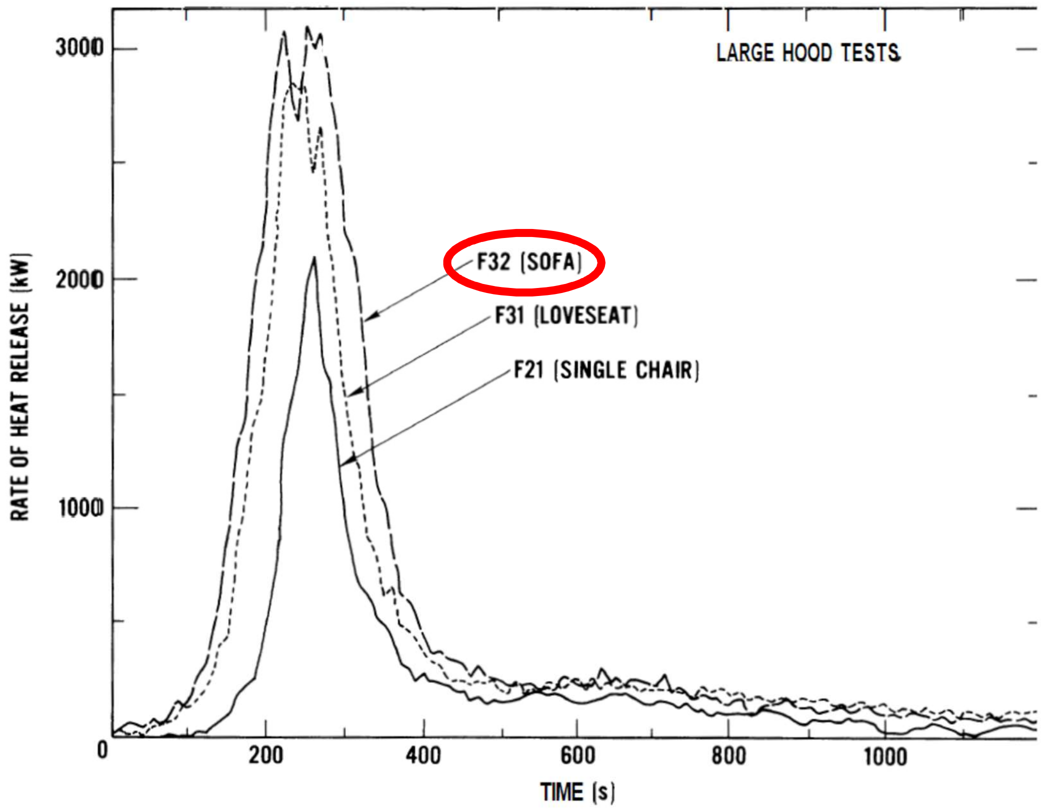


Figure 39: Heat Release Rate vs Time for F32

Although using peak heat release rate would provide a more conservative design, the design scenario assumes that sprinkler activation will control the fire. By controlling the fire, instead of using the value of peak heat release rate, a steady-state heat release rate will be used at the time of sprinkler activation. Table 26 shows the DETACT calculations for determining the actual time a sprinkler would activate and the associated heat release rate at that time. Figure 40 shows the temperature and heat release rate vs time for the “fast” t-squared fire. A sprinkler activation time of 117 seconds was found with a heat release rate of 643 kW. The design will incorporate a peak heat release rate of 750 kW within 117 seconds of the start of the fire to provide a conservative analysis.

Table 26: DETACT Calculation for Sprinkler Activation

INPUT PARAMETERS			CALCULATED PARAMETERS		
Calculation reset	1	0 or 1	R/H	2.5137	-
Ceiling height (H)	1.83	m	W/H	5.4645	-
Room width (W)	10	m	Temperature factor	0.1623	-
Radial distance (R)	4.6	m	Velocity factor	0.0928	-
Ambient temperature (To)	20	C	Calculation time (t)	251	s
Actuation temperature (Ta)	57.22	C	Fire HRR (Q)	2961	kW
Rate of rise rating (ROR)	0	C/min	Gas temperature (Tg)	226.55	C
Response time index (RTI)	45	(m-s)1/2	Gas velocity (Ug)	1.0892	m/s
Fire growth power (n)	2	-	ROR at detector	65.08	C/min
Fire growth coefficient (k)	0.047	kW/s^n	Detector temp (Td)	180.86	C
Fire location factor (kLF)	1	-	Detection trigger	135	250

Representative t2 coeff.	k
Slow	0.003
Medium	0.012
Fast	0.047
Ultrafast	0.180

CALCULATION RESULTS	FT	ROR	
Transport lag time (tl)	23	23	s
Detection time (td)	117	2	s
HRR at detection (Qd)	643	0	kW
HRR w/transport lag (Ql+d)	918	29	kW

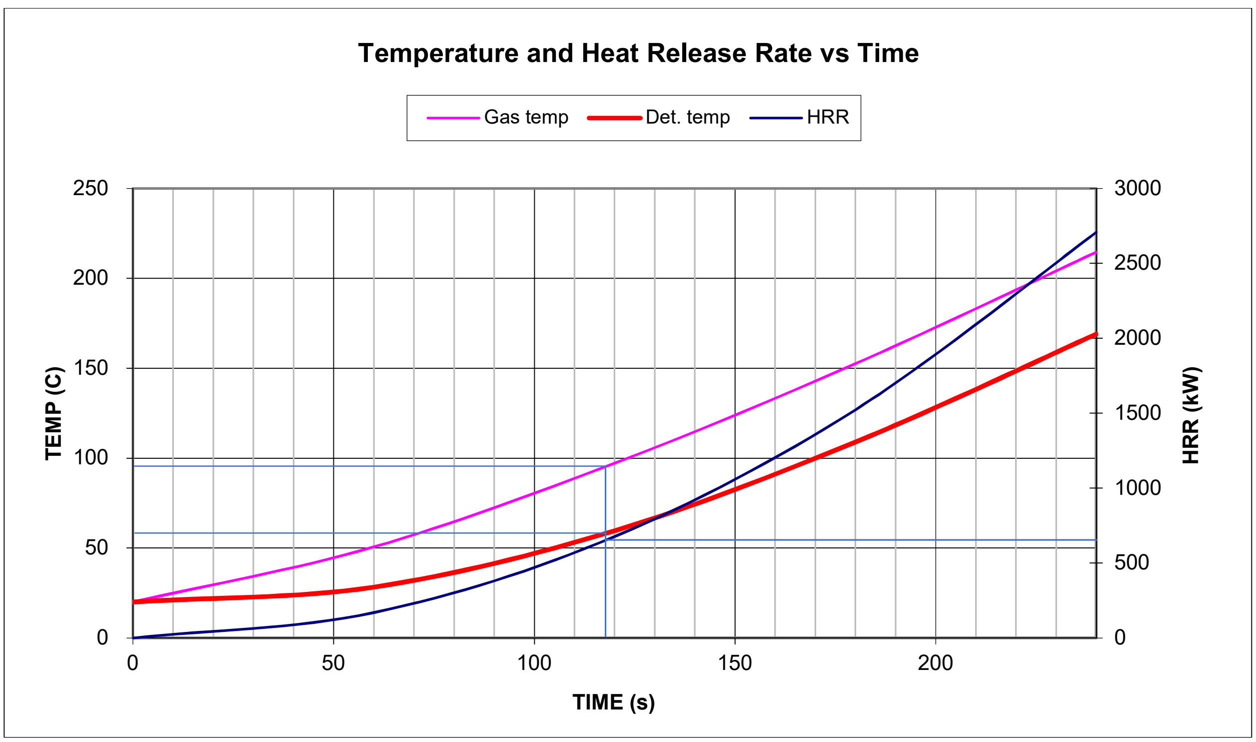


Figure 40: Temperature and Heat Release Rate vs Time for “Fast” t-squared fire

Appendix A Table A.39 {SFPE Handbook 5th Edition} provides yields of fire products and heats of combustion for well-ventilated fires. The table lists four types of flexible expanded polyurethane foam and so an average of all four materials were used for the foam portion of the design. Table 27 shows the values for heat of combustion, carbon monoxide yield, and soot yield for GM21, GM23, GM25, and GM27 and an average of all four materials. As stated earlier, the material composition of the couch is unknown so for the basis of this report a mixture of 70% cellulose material and 30% expanded flexible polyurethane was assumed. The bottom of Table 27 shows the final calculation to obtain a single value for heat of combustion, carbon monoxide yield, and soot yield for the fire.

Table 27: Heat of Combustion and Fire Product Yields

Material	CO Yield	Soot Yield	Heat of Combustion (kJ/kg)
GM21	1.0%	13.1%	17800
GM23	3.1%	22.7%	19000
GM25	2.8%	19.4%	17000
GM27	4.2%	19.8%	16400
Avg. Polyurethane	2.775%	18.75%	17550
Wood	0.4%	1.5%	12400
70% Wood / 30% Polyurethane	1.1%	6.67%	13945

Tenability:
Occupants must be provided with conditions that safely allow them to egress the building. Tenable conditions were measured based on three criteria: visibility, temperature, and carbon monoxide concentration. Visibility is impacted by the amount of smoke concentration that occupants experience when exiting a building. High levels of smoke concentration not only affect the occupant's ability to locate exit signs and doors but may also lead to a decrease in movement speed. High air temperature, or the exposure to heat, may lead to incapacitation and death due to hyperthermia, body surface burns, or respiratory tract burns. Lastly, the main cause of incapacitation and death in a fire is due to the different types of toxic gases that are produced by a fire. Carbon monoxide acts as an asphyxiant attaching to hemoglobin, which normally carries oxygen in the blood, thereby decreasing the amount of oxygen to the body.

The primary factors to determine visibility criteria are the geometry of the space and occupants' familiarity with the building. Various research has been conducted on visibility by fire researchers with acceptable values within the range of 4' to 65'. Based on Table 61.3 of the SFPE Handbook, occupants familiar with the building would require 13' of visibility while those unfamiliar with the building would require 43'.[2] Additionally, it is recommended to use a visibility distance of 5' for small enclosures with short travel distances and 33' for large enclosures with long travel distances. Although incoming freshman may not be familiar with the building at the start of school, within a short time they would become familiar with the building layout. Guests would typically be accompanied by a resident who would be familiar with the building as well. However, due to the long travel distances within the corridors, a conservative visibility of 33' was selected.

The three main ways exposure to heat can lead to incapacitation or death is: heat stroke, body surface burns, and respiratory tract burns. Heat stroke, or hyperthermia, is caused by a prolonged exposure to temperatures below 248°F. The humidity in the air also plays a role with a higher moisture content having a larger impact on the occupants. Figure 41 shows a Temperature vs Time graph illustrating the tolerable time occupants can withstand a given temperature depending on humid or dry conditions. For convected heat, temperatures over 248°F can result in surface burns to occupants and only requires a short exposure to higher temperatures. Temperatures below 248°F can result in hyperthermia but require a longer exposure time. Lastly, studies have shown that steam at around 212°F is capable of causing severe burning to the respiratory tract. This design was set at a conservative temperature limit of 176°F in line with tolerable conditions for a 20 minute exposure time in humid conditions.

Fig. 63.28 Thermal tolerance for humans at rest, naked skin exposed, with low air movement (less than 30 m/min) (Adapted from Blockley [111]. See text and Table 63.17 for discussion of data points A to D) [110, 113, 114]

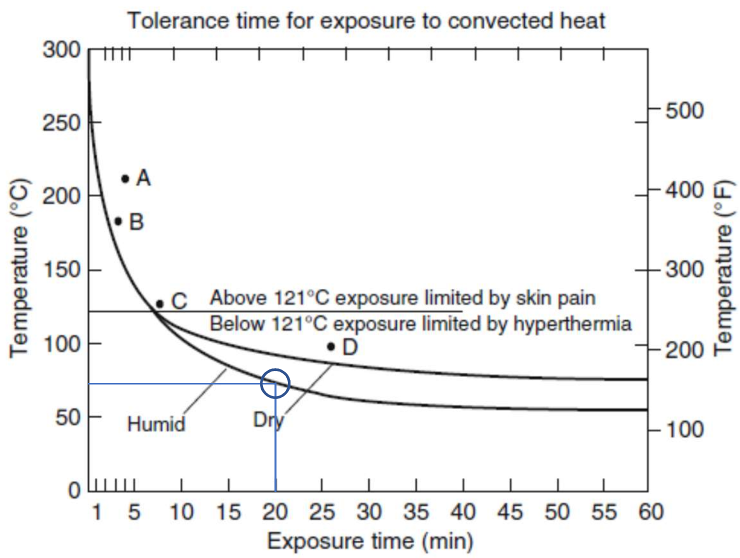


Figure 41: Temperature vs Exposure Time for Tolerance to Heat

Fires produce many toxic gases which can lead to incapacitation or death with carbon monoxide being present in almost all fires. Carbon monoxide works as an asphyxiant by combining with hemoglobin to form carboxyhemoglobin (COHb) thus reducing the amount of oxygen being supplied to the body. The actually amount of COHb in the blood is what leads to incapacitation or death. Studies have shown for an average person 40 %COHb leads to incapacitation however, for conservative estimates and because families with young children might be present, a 30 %COHb was used. Using the Liner Uptake Stewart Model equation[3]:

$$\%COHb = (3.317 * 10^{-5}) * (ppm\ CO)^{1.036} * (V_E) * (t)$$

$\%\ COHb = 30$

$V_E = 25$ L/min (walking)

$T = 20$ min

a value of ~1,400 ppm CO is calculated based on a 20 minute exposure with a 70 kg man walking. Due to the variations in students, a conservative 1,000 ppm CO tenability limit was selected. Table 28 provides a summary of the tenability criteria for the performance based design. All criteria for tenability was analyzed at a height of 6' from the walking surface.

Table 28: Tenability Criteria at 6' Above Walking Surface

Criteria	**Limit**
Visibility	33 feet (10 m)
Temperature	176°F (80° C)
Toxicity	1,000 ppm CO

ASET:
The available safe egress time (ASET) is calculated by the time untenable conditions are reached within the building. Pyrosim, created by Thunderhead Engineering, is a graphical interface that provides easier capability of modeling the fire and geometry of the enclosure. The backbone behind the processing of the simulation is Fire Dynamics Simulator (FDS) and Smoke View, both developed by the National Institute of Standards and Technology. Figure 42 shows the actual condition the fire design scenario was modeled after. Figure 43 provides the Pyrosim geometry overlaid on the Level 2 floor plan for reference. The location of the fire and couch are circled in red.

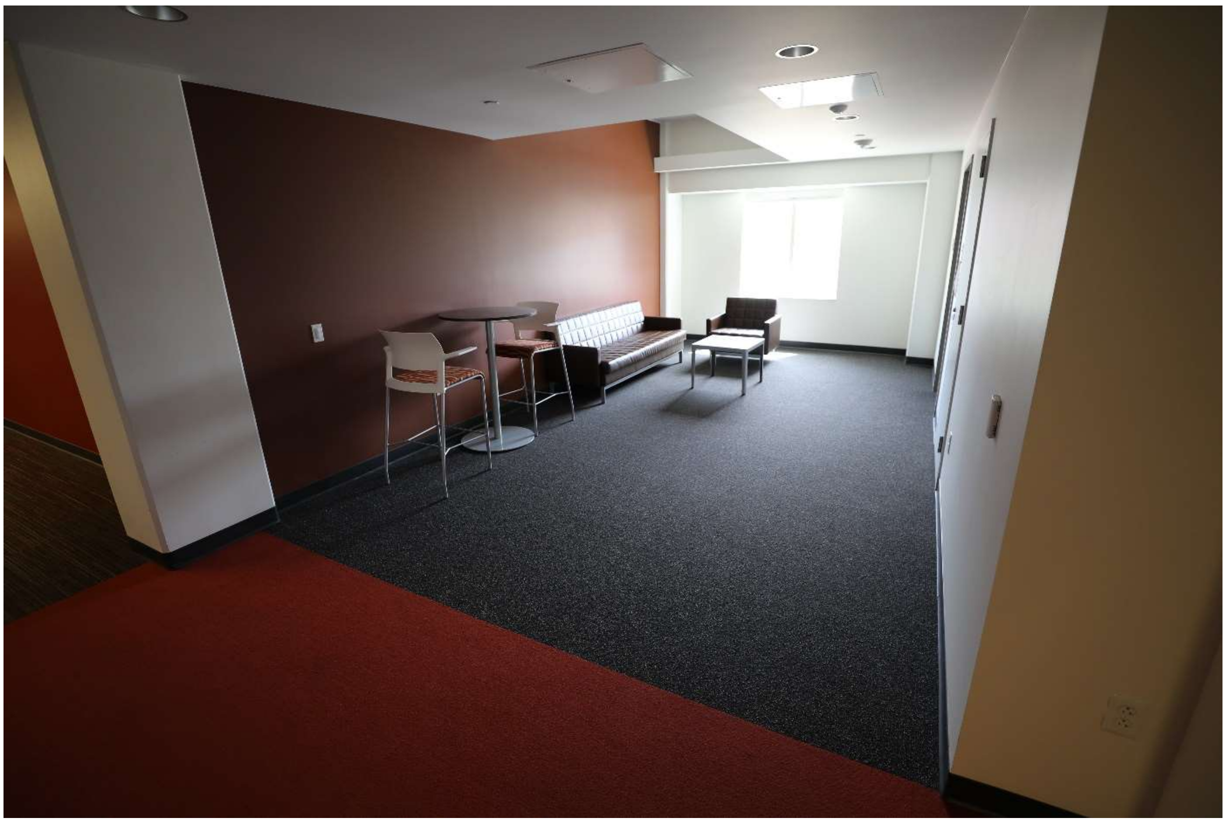


Figure 42: Design Scenario Condition

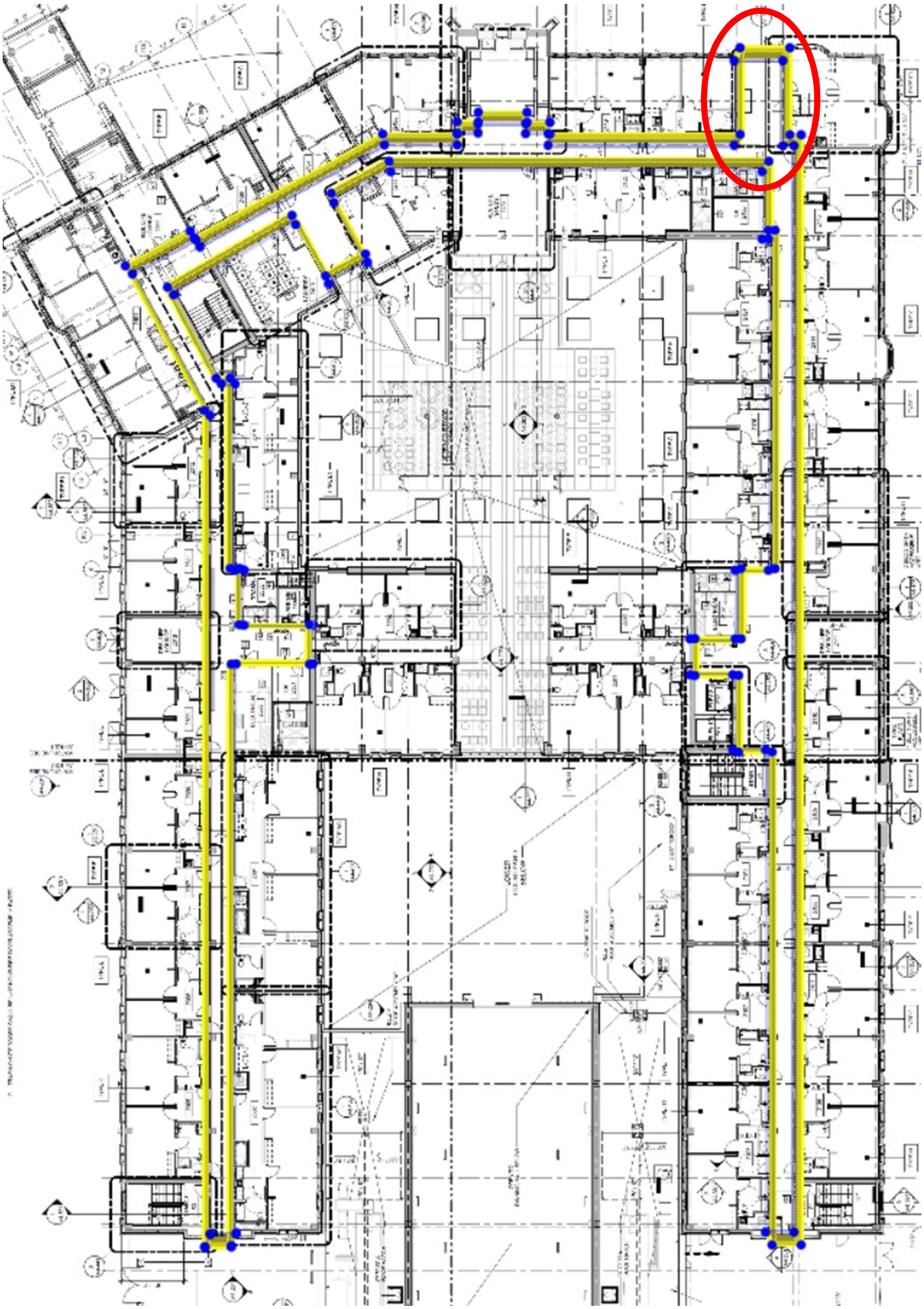


Figure 43: Level 2 Pyrosim model with Fire Location

Smoke View was used to capture the tenability criteria conditions at a height of 6’ above the walking surface at 30 second time intervals. Smoke View provides a color scale to be able to determine levels of acceptance with black being the threshold set. For visibility, any regions that fall under the black bar would be considered the point at which tenability is not achieved since it represents that visibility would fall below 33’. By the 120 second mark, visibility has dropped below 33’ for most of the southeast portions of the building and thus conditions are considered to be untenable. Figures 44-48 show the visibility during the fire model.

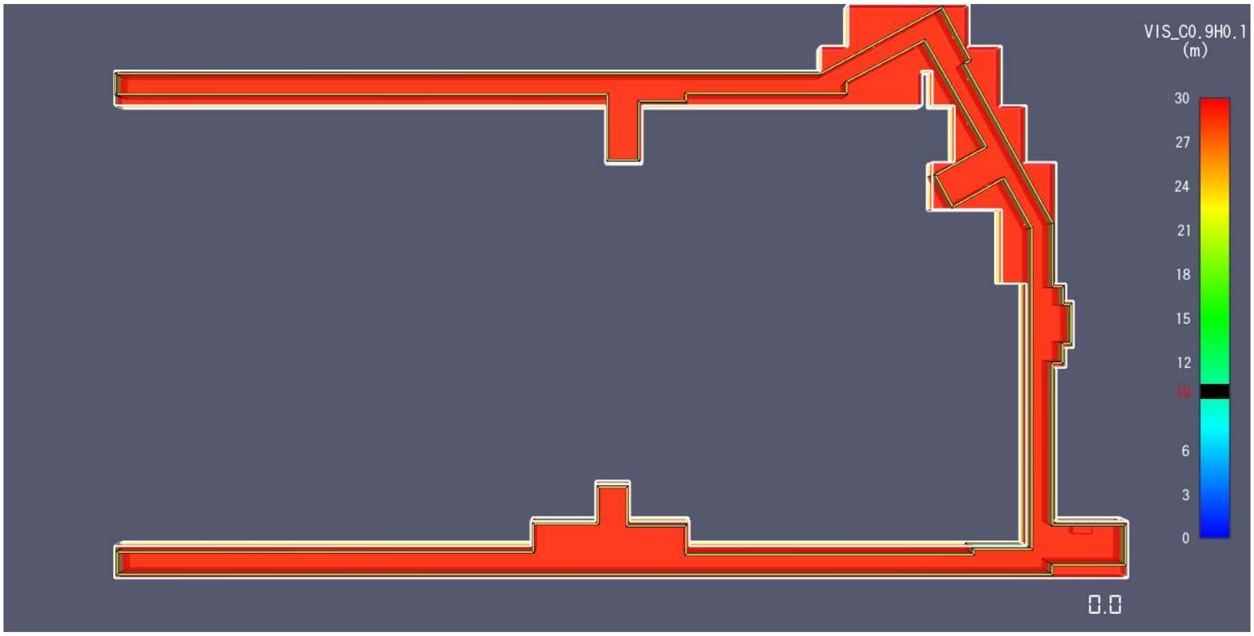


Figure 44: Visibility 6’ above Floor at 0s.

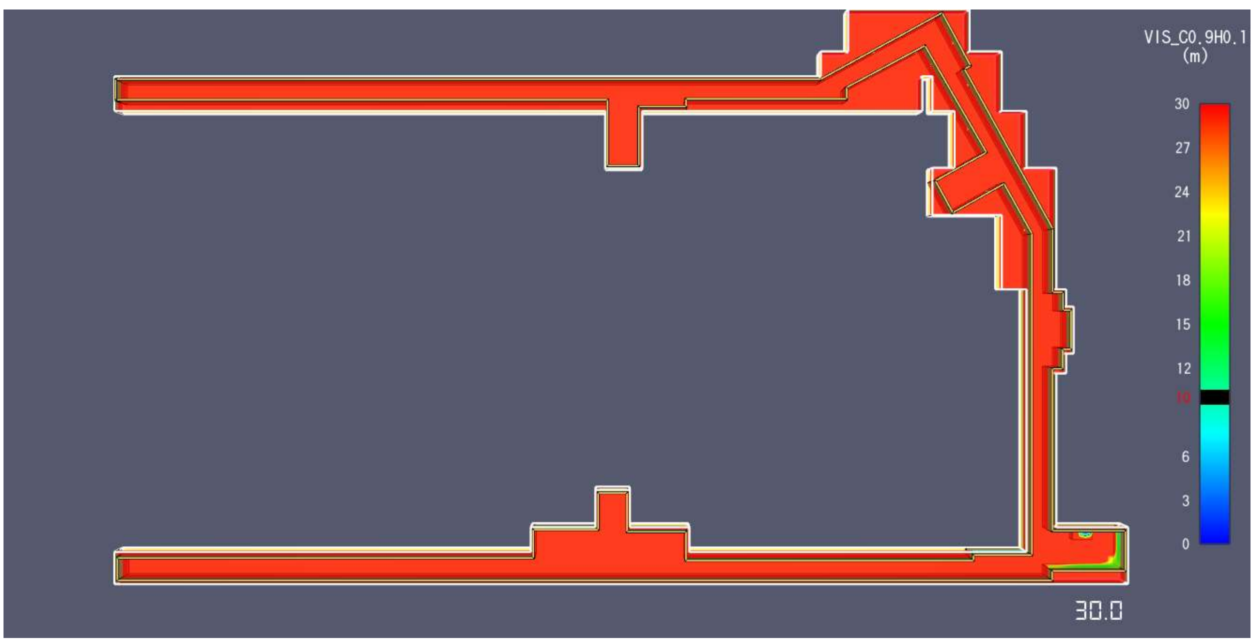


Figure 45: Visibility 6’ above Floor at 30s.

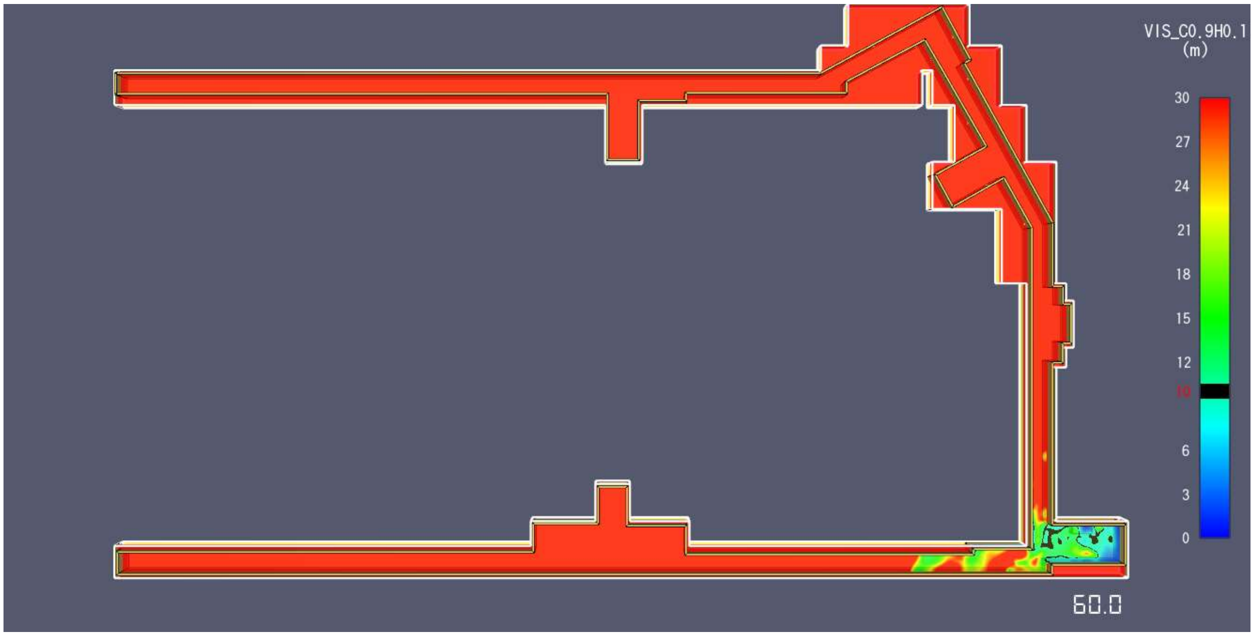


Figure 46: Visibility 6’ above Floor at 60s.

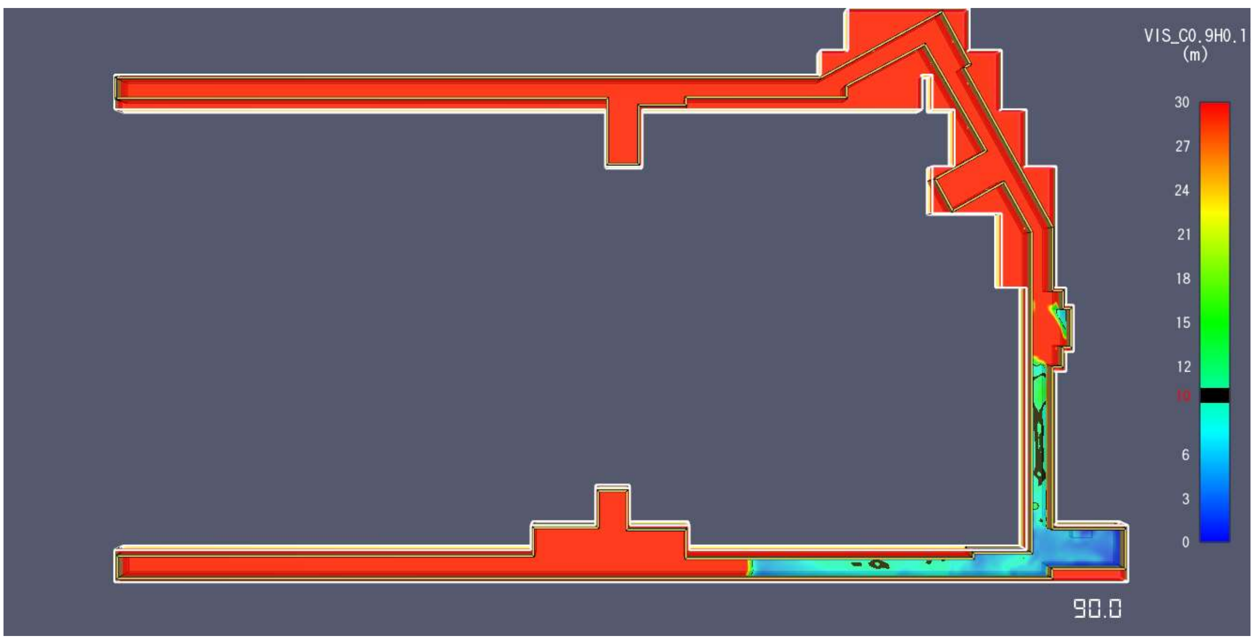


Figure 47: Visibility 6’ above Floor at 90s.

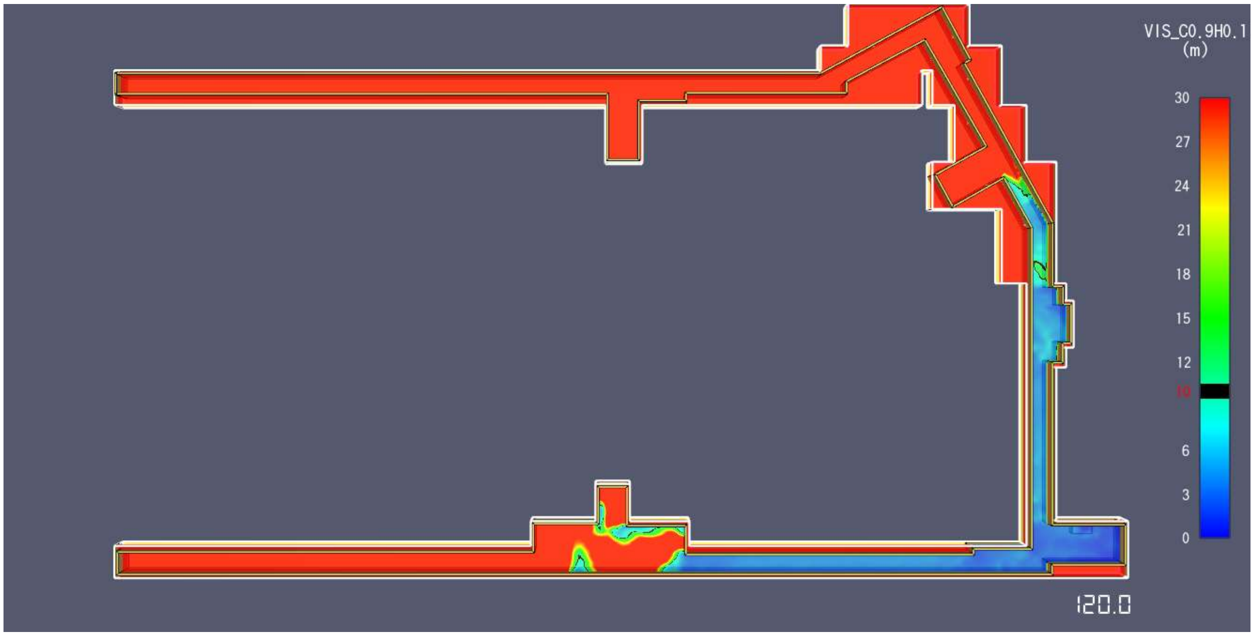


Figure 48: Visibility 6' above Floor at 120s.

For temperature, any regions that fall above the black bar would be considered the point at which tenability is not achieved since it represents that temperature has risen above 176°F. By the 180 second mark, temperature has risen above 176°F for most of the southeast portions of the building and thus conditions are considered to be untenable. Figures 49-55 show the temperature during the fire model.

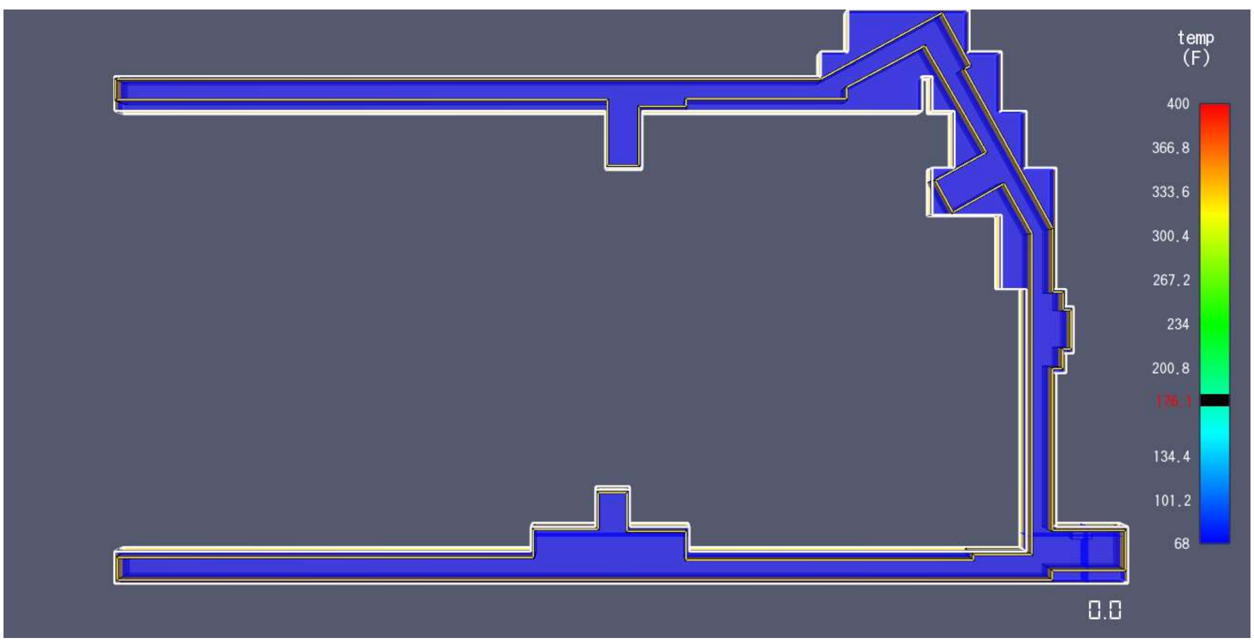


Figure 49: Temperature 6' above Floor at 0s.

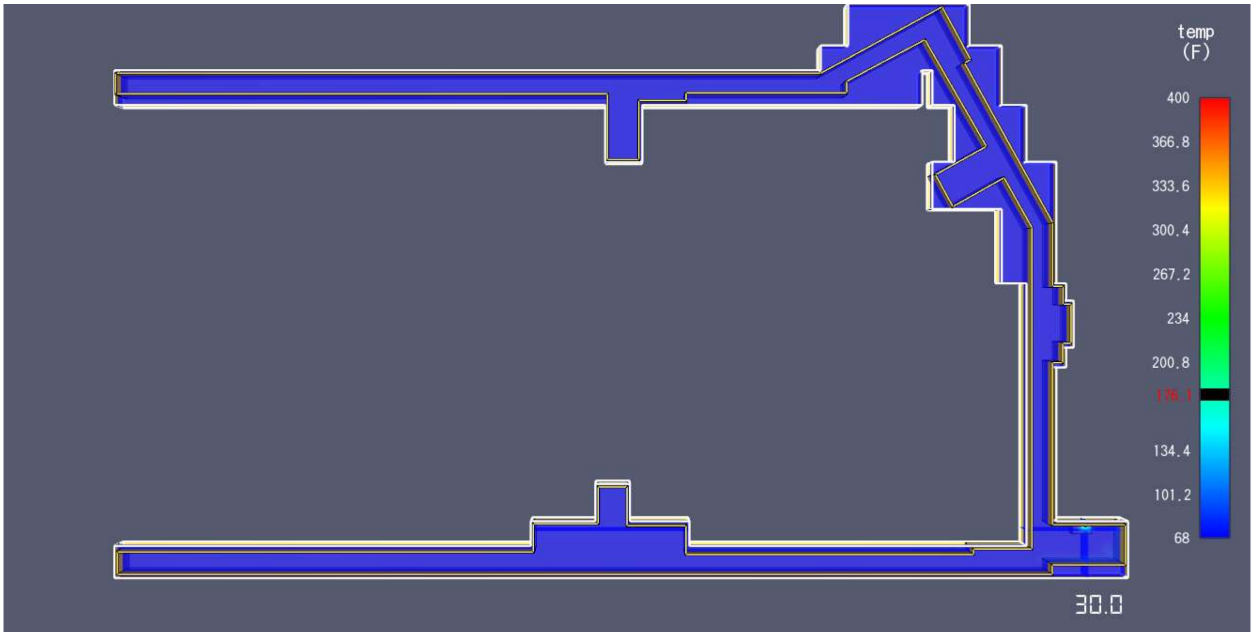


Figure 50: Temperature 6’ above Floor at 30s.

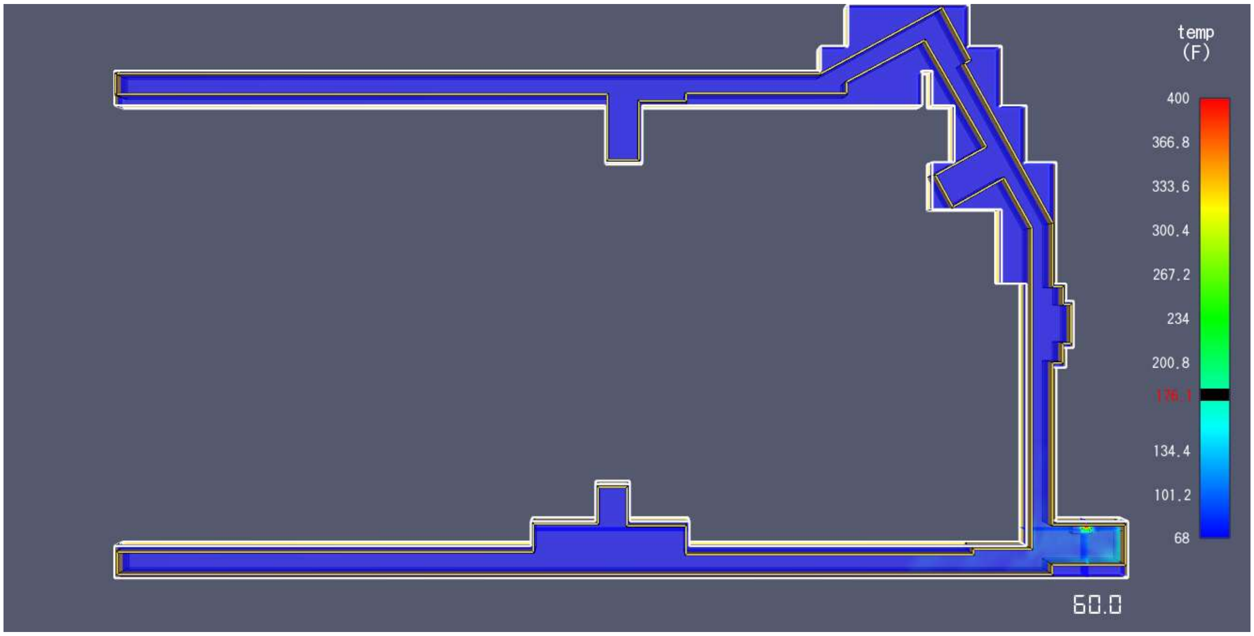


Figure 51: Temperature 6’ above Floor at 60s.

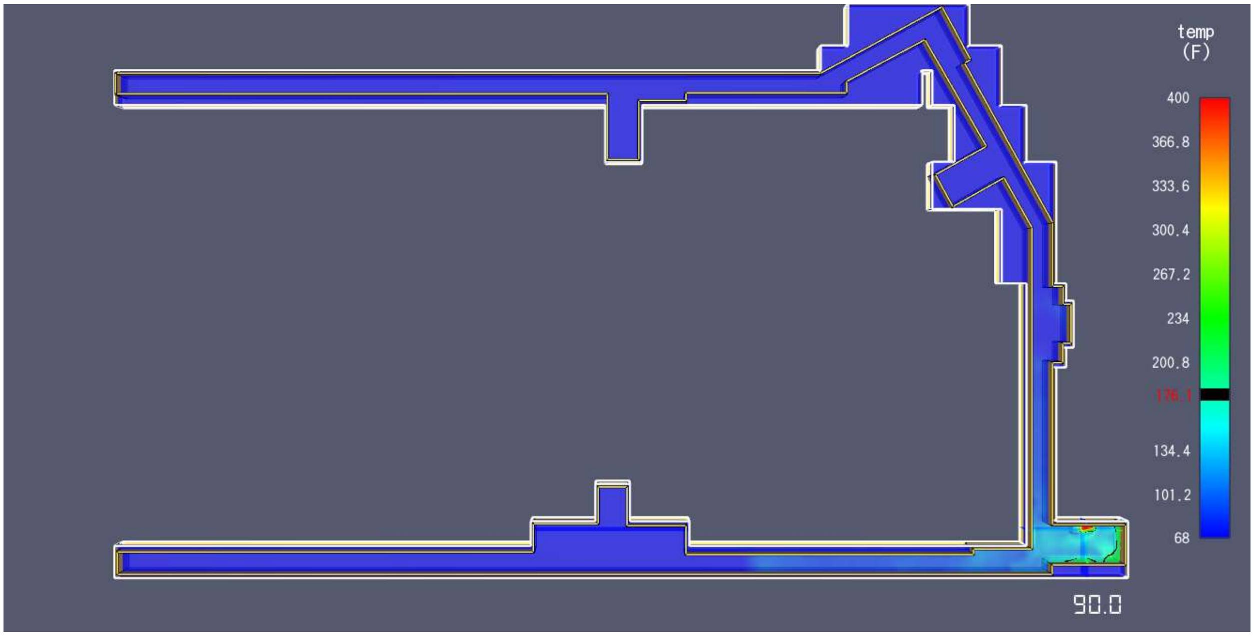


Figure 52: Temperature 6’ above Floor at 90s.

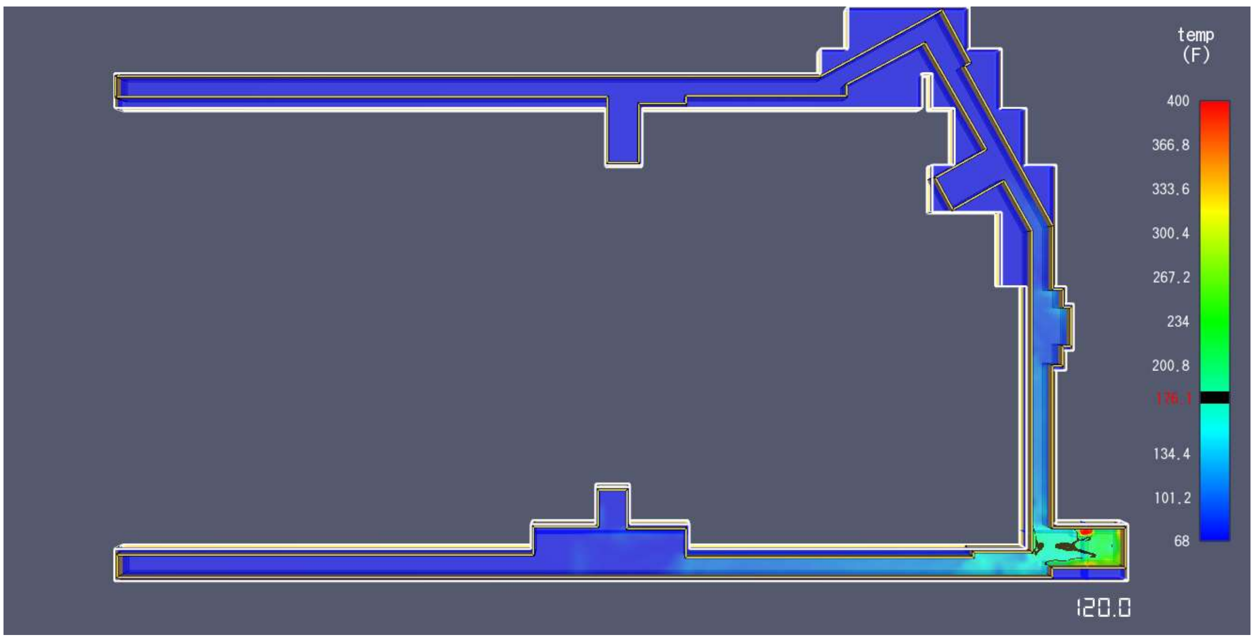


Figure 53: Temperature 6’ above Floor at 120s.

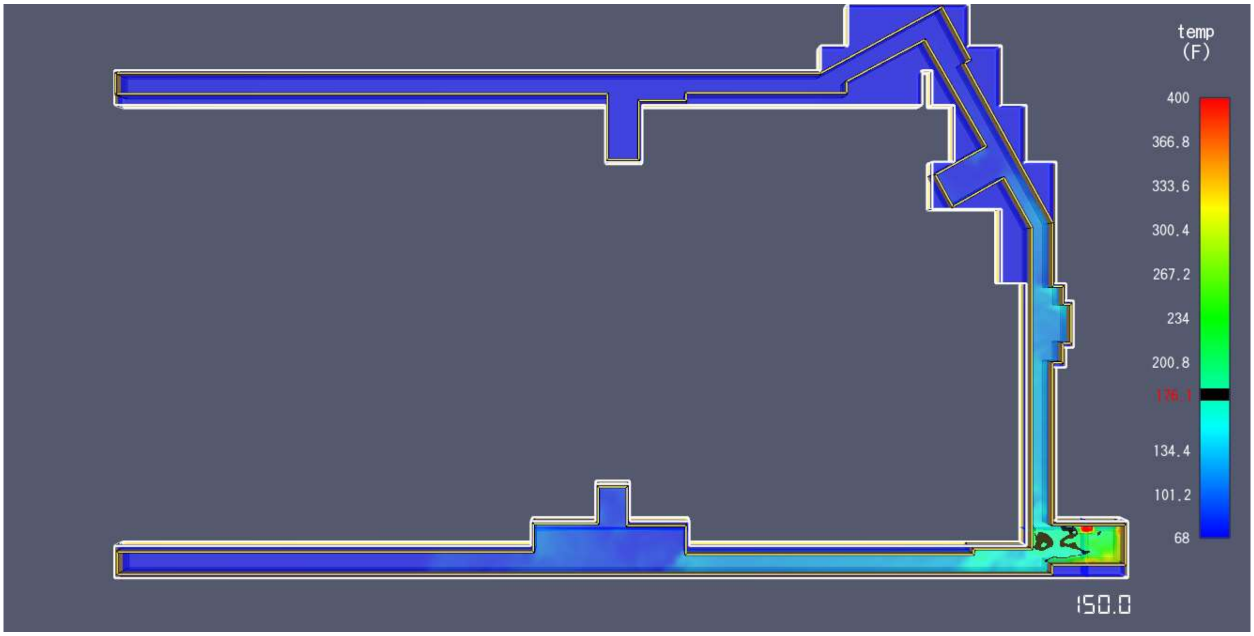


Figure 54: Temperature 6’ above Floor at 150s.

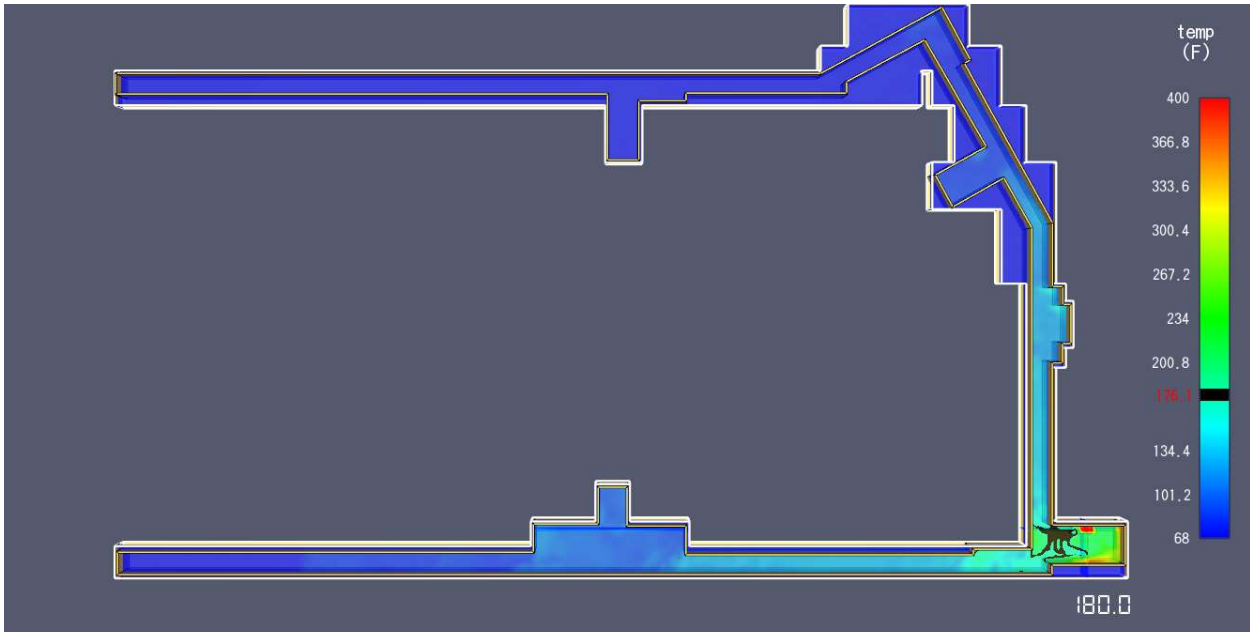


Figure 55: Temperature 6’ above Floor at 180s.

For toxicity by the end of the run the concentration of CO never exceeded 900 ppm. Thus, conditions were tenable throughout the entire run time of the model. Figures 56 and 57 show the concentration of Carbon Monoxide in parts per million at the start and end of the fire model.

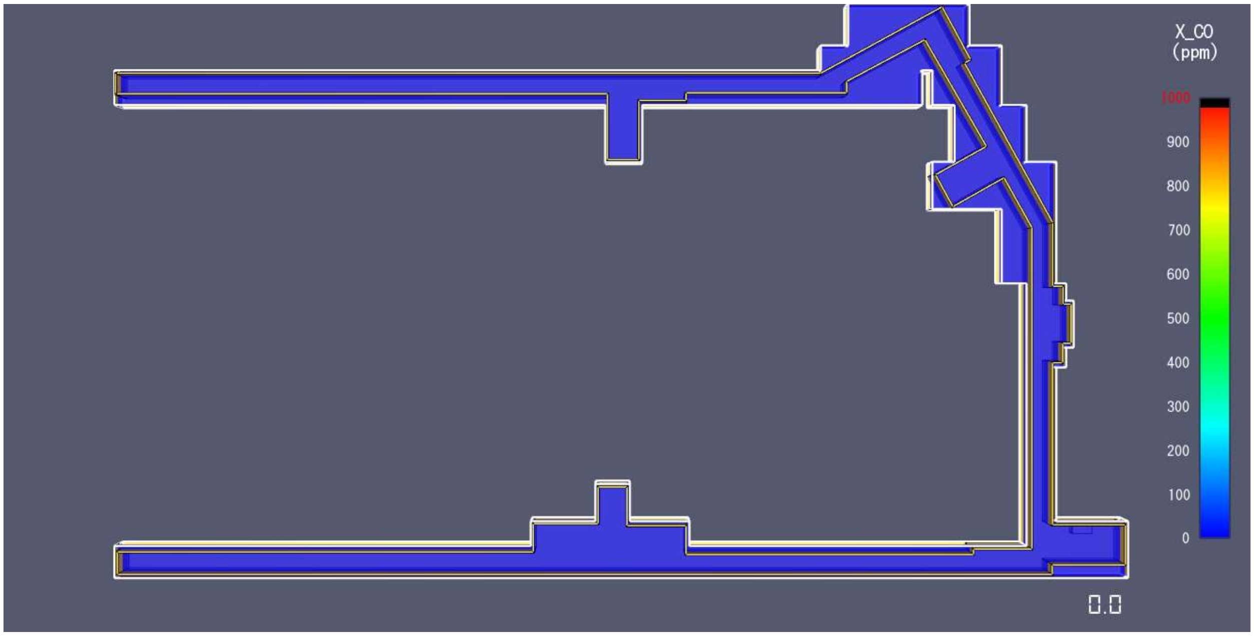


Figure 56: ppm CO 6’ above Floor at 0s.

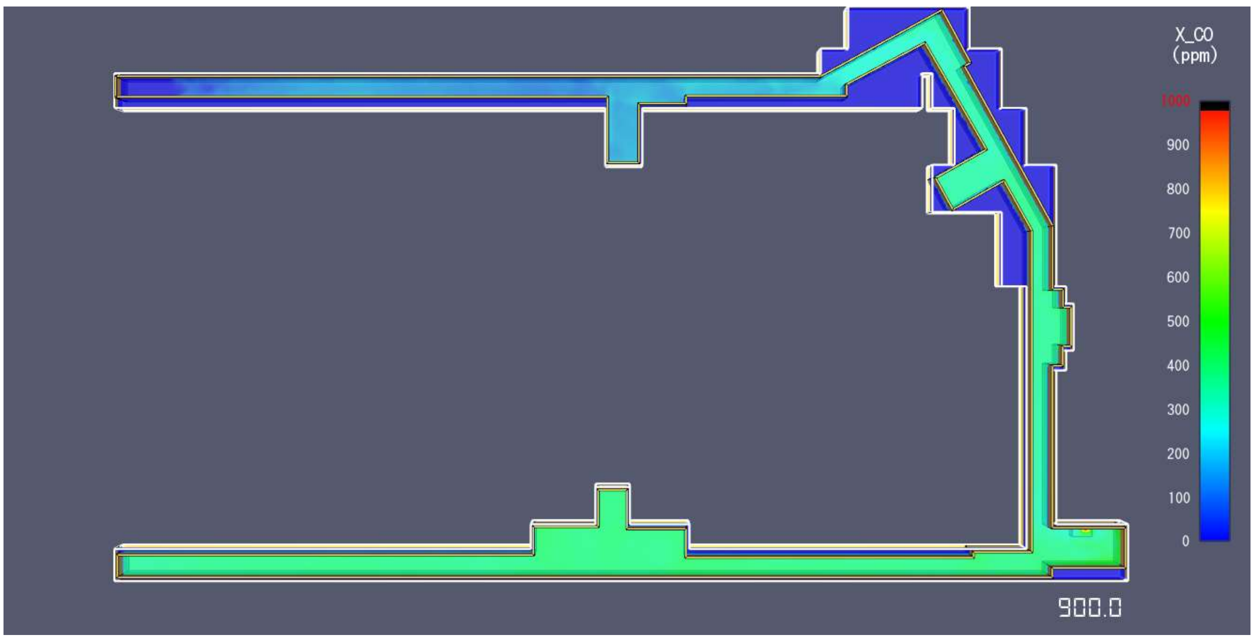


Figure 57: ppm CO 6’ above Floor at 900s.

Based on the results, untenable conditions occurred within 120 seconds of the start of the fire. Therefore, the available safe egress time before the corridor becomes untenable is 2 minutes.

RSET:
The required safe egress time (RSET) is the time required for occupants to safely exit the building. RSET is comprised of three elements: Detection time (t_{det}), Pre-evacuation time (t_{pre}), and Travel time (t_{trav}).

Detection time is the time at which the fire is first ignited and first detected by an individual or device. For this model activation of the sprinkler system was determined to be the first detection of the fire. Based on the data in Table 26, a sprinkler would activate within 117 seconds of the fire being started.

Pre-evacuation time is the time when the first signal or warning is given and first movement is made to evacuate the building. Data was collected by Fahy and Proulx that found an average pre-evacuation time of 3.1 minutes for a mid-rise apartment with good alarm performance.[4]

Travel time was calculated using an egress modeling software known as Pathfinder created by Thunderhead Engineering. The geometry of the entire building was created with individual rooms and doors. Each room was loaded with the number of occupants calculated based on the California Building Code requirements for occupant load densities. Figure 58 shows the building modeled in Pathfinder as well as the occupants within the building. Safe egress was assumed to be achieved once the occupants reached an exit door or exit stair.

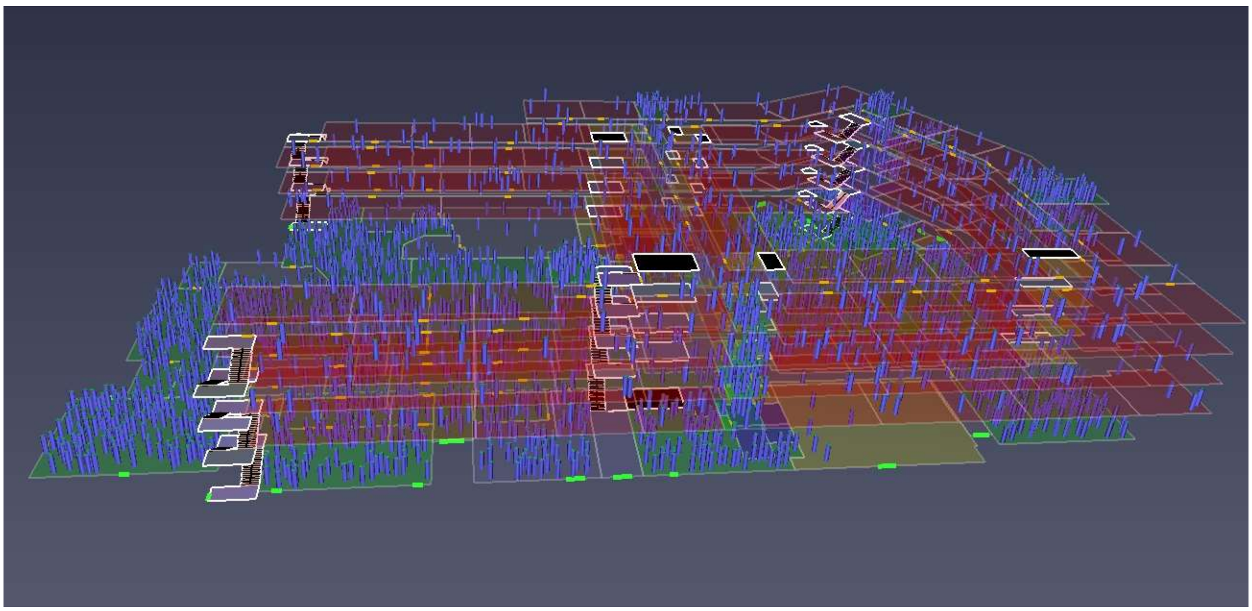


Figure 58: Pathfinder model of Building V

Figures 59-63 show screen shots of the evacuation model being run at 60 second intervals. Through the use of Pathfinder an evacuation time of 213 seconds was found to be required to egress Level 2.

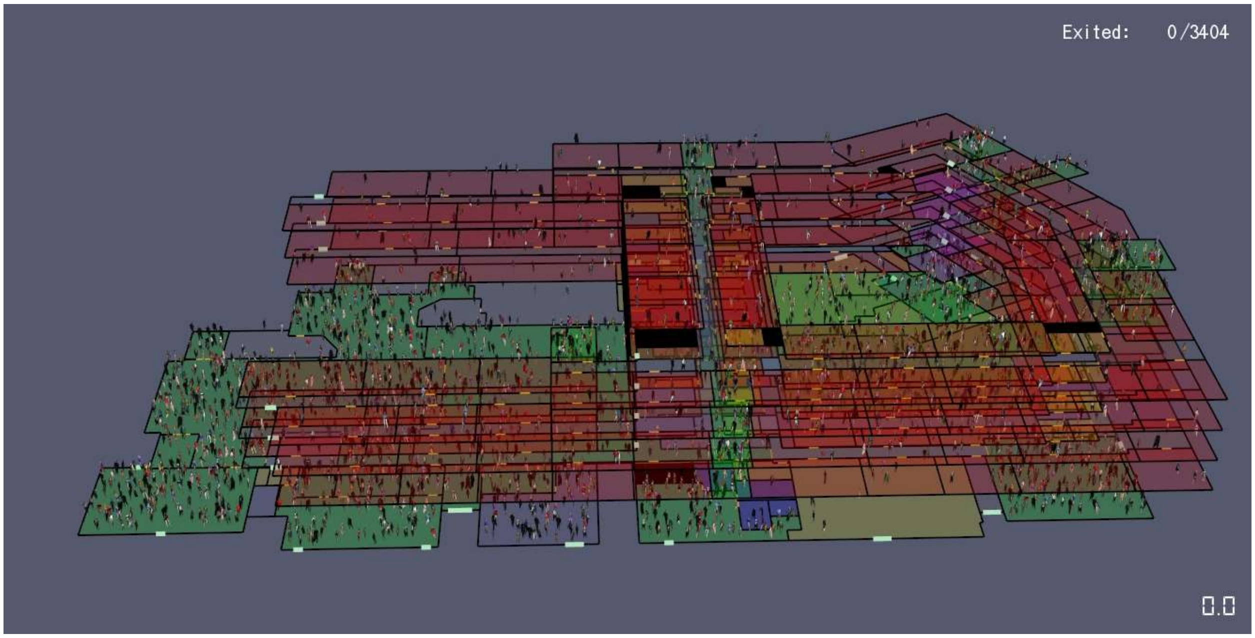


Figure 59: Evacuation sequence at time 0s.

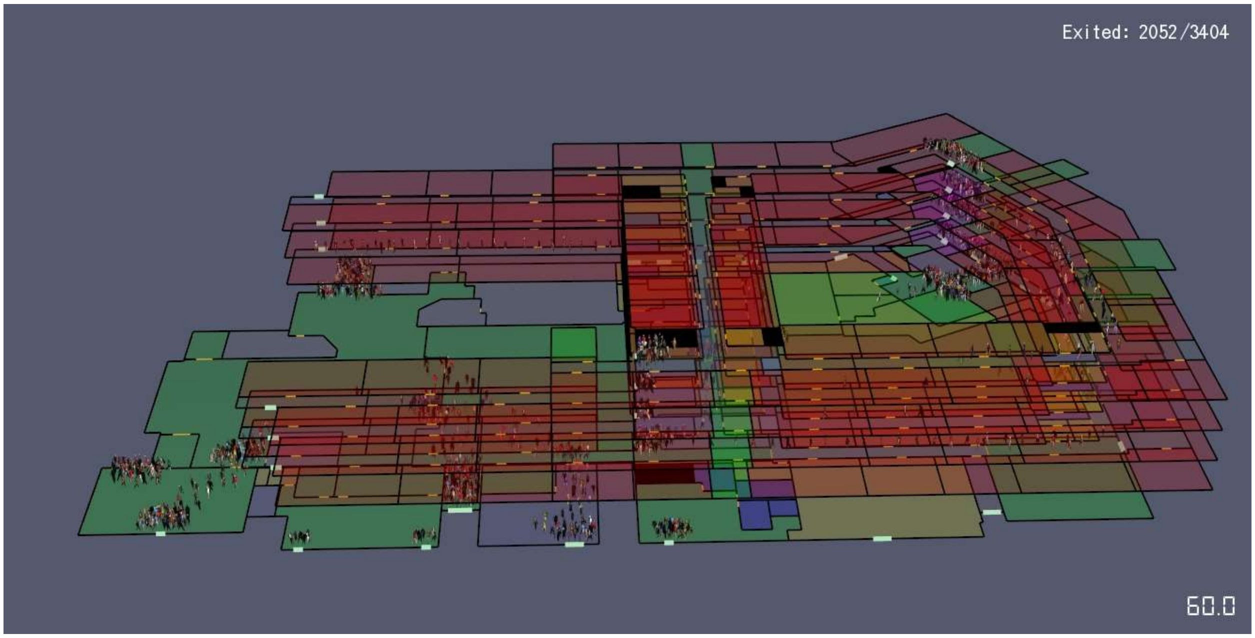


Figure 60: Evacuation sequence at time 60s.

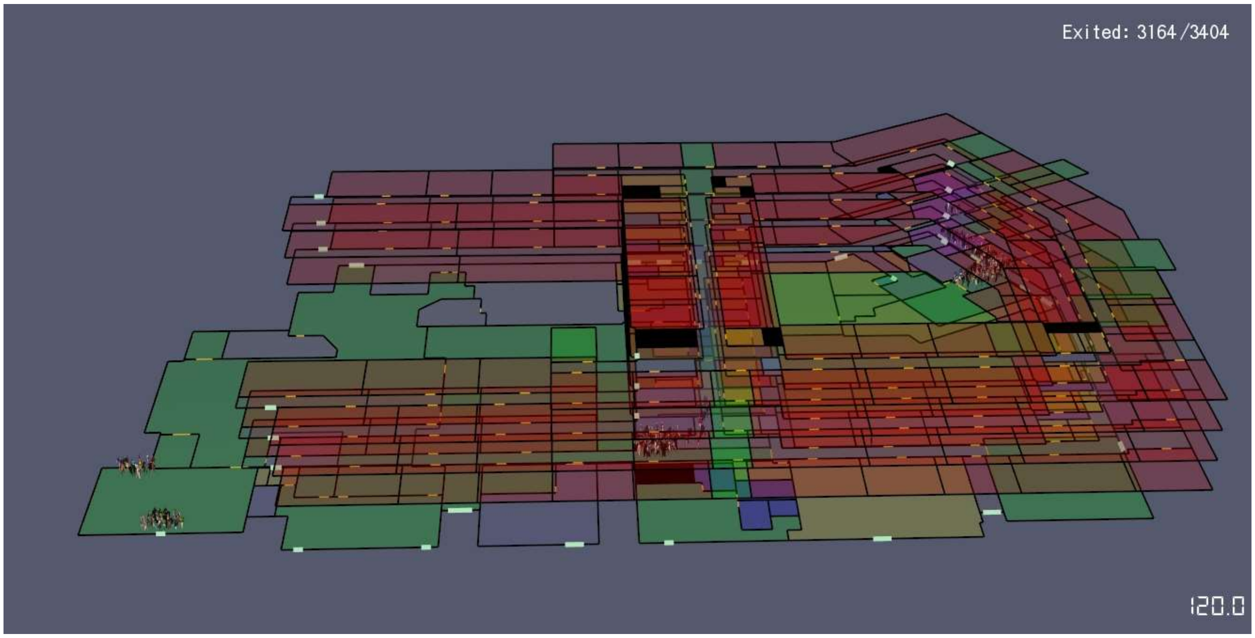


Figure 61: Evacuation sequence at time 120s.

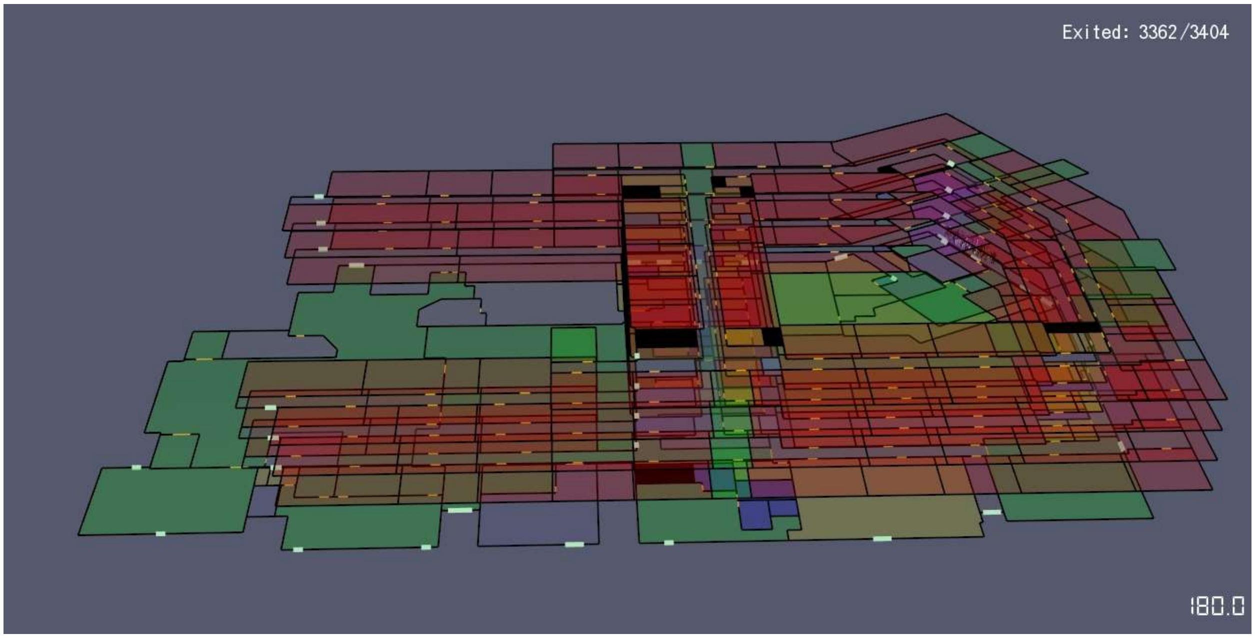


Figure 62: Evacuation sequence at time 180s.

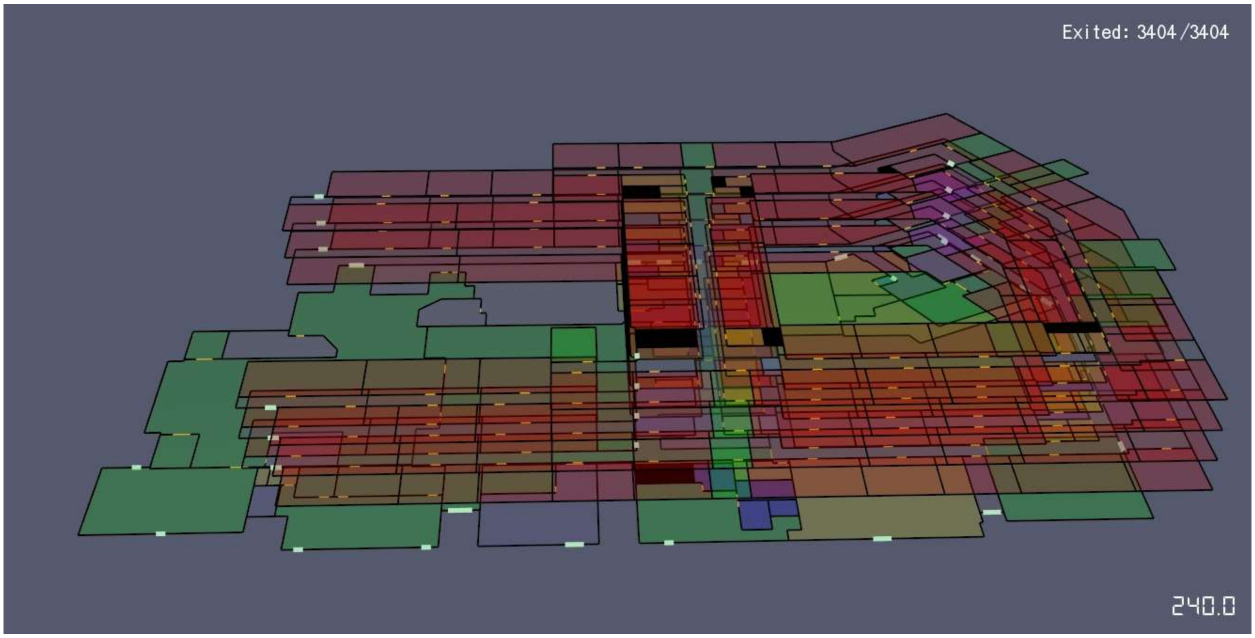


Figure 63: Evacuation sequence at time 240s.

Combining the three elements required for egress timing, RSET = 520 seconds.

PERFORMANCE BASED DESIGN SUMMARY

The performance based design shows visibility was the controlling tenability criteria limiting the available safe egress time to under 2 minutes. The required safe egress time however was calculated to be around 9 minutes. Thus, ASET was not greater than RSET and so the current design of Building V would not be safe for building occupants. Table 29 summarizes the findings of the performance based design based on a RSET of 520 seconds.

Table 29: Summary of Tenability Criteria

Visibility	Temperature	Toxicity
Fail @ 120s	Fail @ 180s	Passed

CONCLUSION AND RECOMMENDATIONS

This report analyzed Building V in detail for compliance with the prescriptive requirements of the 2013 California Building Code. The building met all requirements of area and height based on a Type IB construction type and the required structural fire resistance, fire resistance separations, and flammability were also found to comply with code provisions. The means of egress was also correctly designed per the requirements of Chapter 10 of the CBC for number of exits, egress widths, travel distances, and exit spacing. Building V was also designed with a fully compliant fire alarm system that provided automatic smoke detection and an emergency voice/alarm communication system. The fire alarm system was designed per the 2013 NFPA 72 for the location and spacing of initiating and notification devices. The fire alarm system also worked to assist in the required compartmentation for smoke control closing dampers and fire doors when required. The last prescriptive component was the fire sprinkler design which was per the 2013 NFPA 13. Based on the design criteria and the hydraulic calculations, the types of sprinklers and standpipes as well as the components of the fire sprinkler system were also compliant to the prescriptive design. Although built to comply with all prescriptive code requirements, once a certificate of occupancy was given and the building was occupied, furniture was placed within alcoves of the rated corridor. Section 1018.6 {2013 CBC} states that “Fire-resistance rated corridors shall be continuous from the point of entry to an exit, and shall not be interrupted by intervening rooms." By creating an occupied alcove, it can be interpreted that an intervening room was created within the rated corridor thus making the building no longer compliant with the prescriptive requirements.

The performance based design provided an alternative approach for compliance that analyzed a life safety goal and objective. The overall life safety goal was to provide safe egress for the building occupants with an objective that the allowable safe egress time was greater than the required safe egress time. Based on the fire scenario of a couch within the rated corridor, a design fire was modeled with the three criteria of temperature, toxicity, and visibility being measured for tenable conditions. Based on the criteria, visibility was found to be untenable after 120 seconds and temperature was found to be untenable after 180 seconds. Toxicity levels of carbon monoxide were maintained low enough that they were not found to create untenable conditions. Visibility was the limiting factor with the allowable safe egress time to be 120 seconds. A Pathfinder model was also created to determine the required safe egress time which when coupled with detection time and pre-movement time, the required safe egress time was found to be 520 seconds, much higher than the 120 seconds when conditions would be untenable.

Based on both the prescriptive and performance based design, keeping furniture within the rated corridor would not meet the California Building Code nor the life safety goal of evacuating the building occupants safely. Two recommendations would be made to assist in a safer environment for the building occupants. The first recommendation would be to completely remove the furniture from the rated corridors limiting the use to circulation and limiting the possibility of a fire within the rated corridor. If that is not possible, the second recommendation would be to create a rated partition to separate and compartment the alcove from the rated corridor. The additional protection of the rated walls and rated and smoke gasketed doors would allow for increased time before conditions within the corridor would be untenable.

REFERENCES

[1] V. Babrauskas, J. Lawson, W. Walton, & W. Twiley. (1982) Upholstered Furniture Heat Release Rates Measued with a Furniture Calorimeter. U.S. Department of Commerce.

[2] T. Yamada & Y. Akizuki. Visibility and Human Behavior in Fire Science. SFPE Handbook 5th Edition.

[3] R.D. Stewart, J.E. Peterson, T.N. Fisher, M.J. Hosko, E.D. Baretta, H.C. Dodd, and A.A. Hermann, "Experimental Human Exposure to High Concentrations of Carbon Monoxide," *Archives of Environmental Health,* 26, p. 1(1973)

[4] Fahy, R.F. and Proulx, G. (2001) Towards creating a database on delay times to start evacuation and walking speeds for use in evacuation modeling. In: Proceedings of the second international symposium on human behavior in fire, 26/28 March 2001, Massachusetts Institute of Technology, USA. Interscience Communications (London, UK) pp175-179.

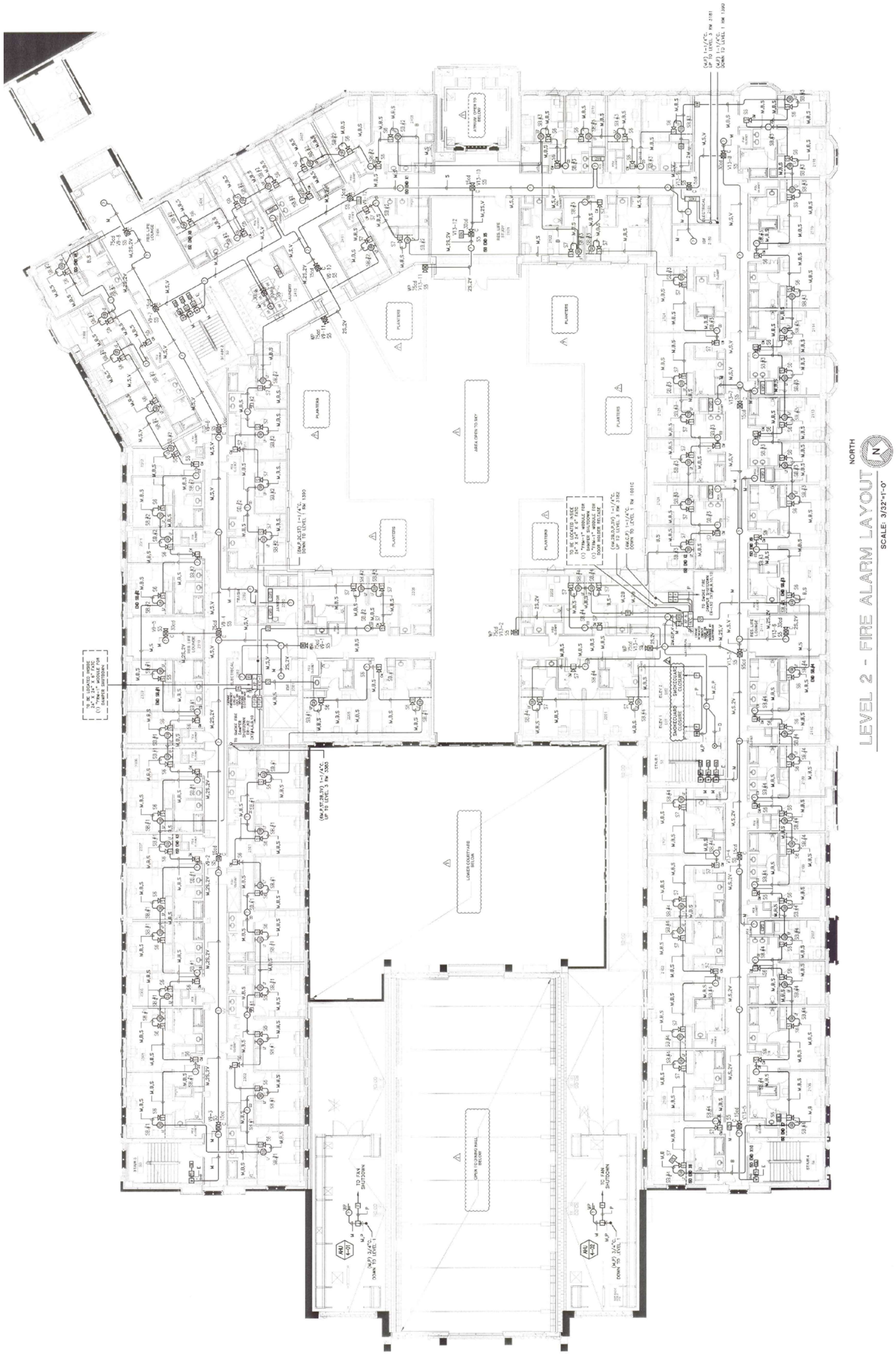
[5] 2013 California Building Code.

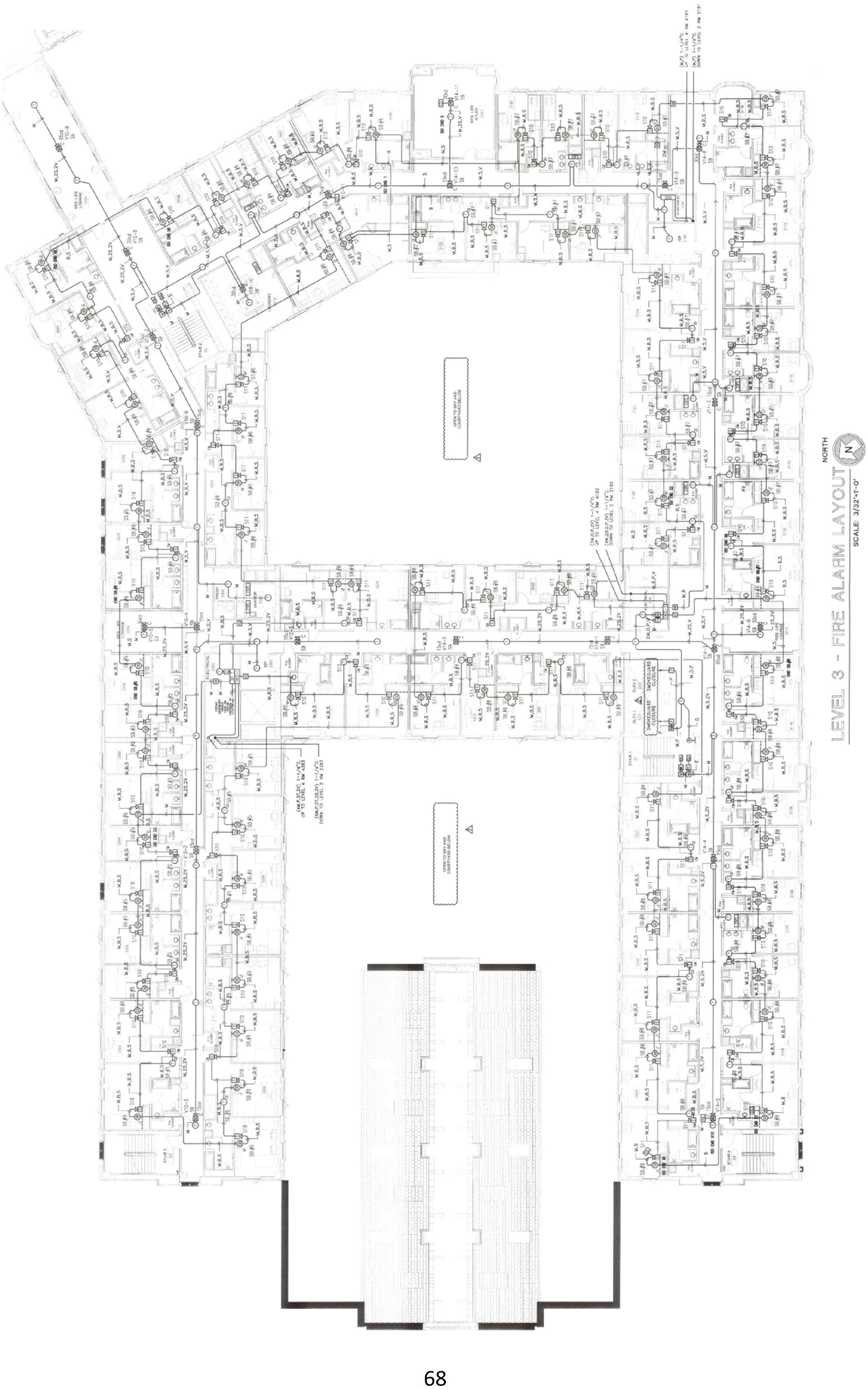
[6] 2013 NFPA 72.

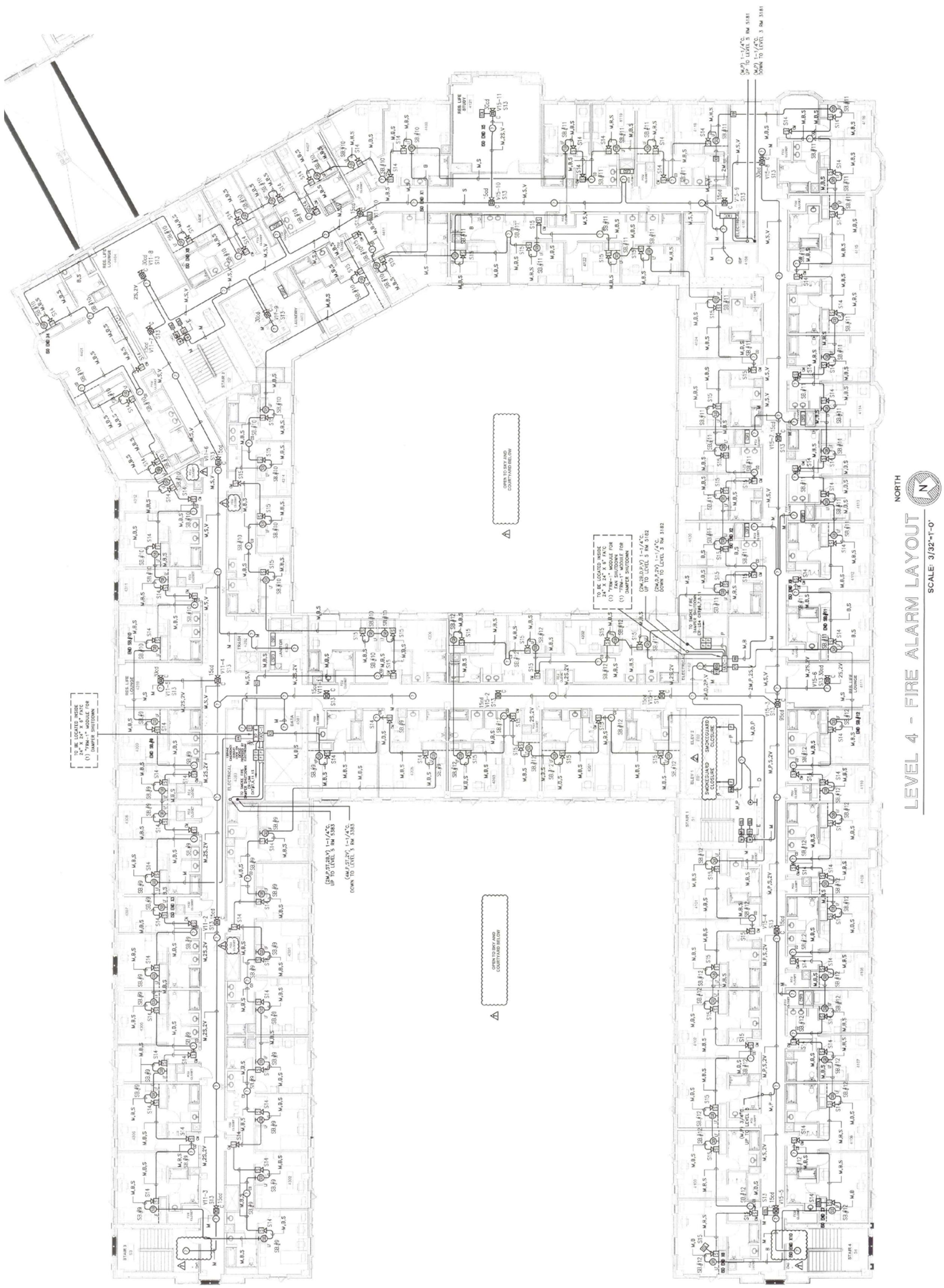
[7] 2013 NFPA 25.

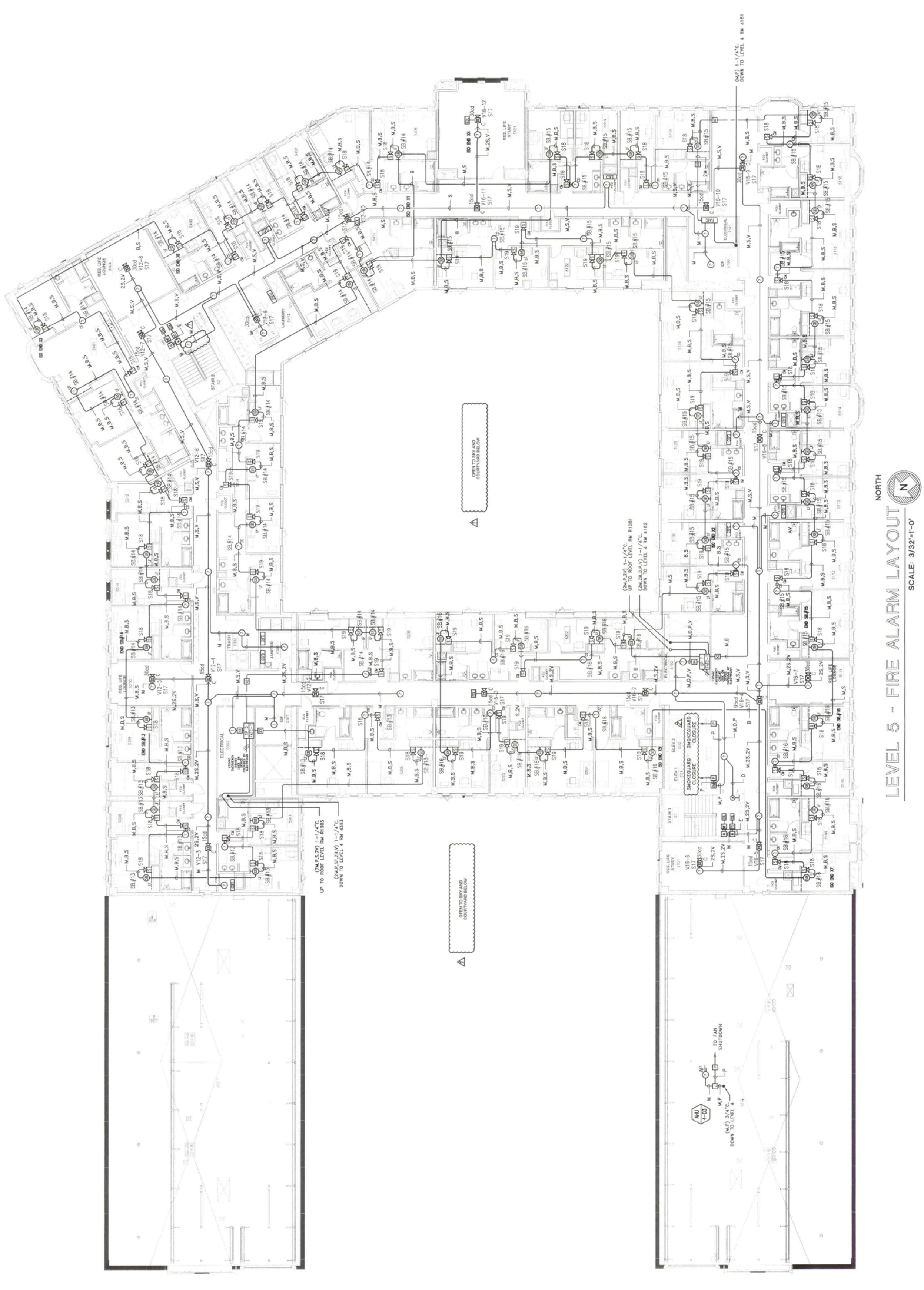
[8] 2015 NFPA 101.

Appendix A – Fire Alarm Drawings

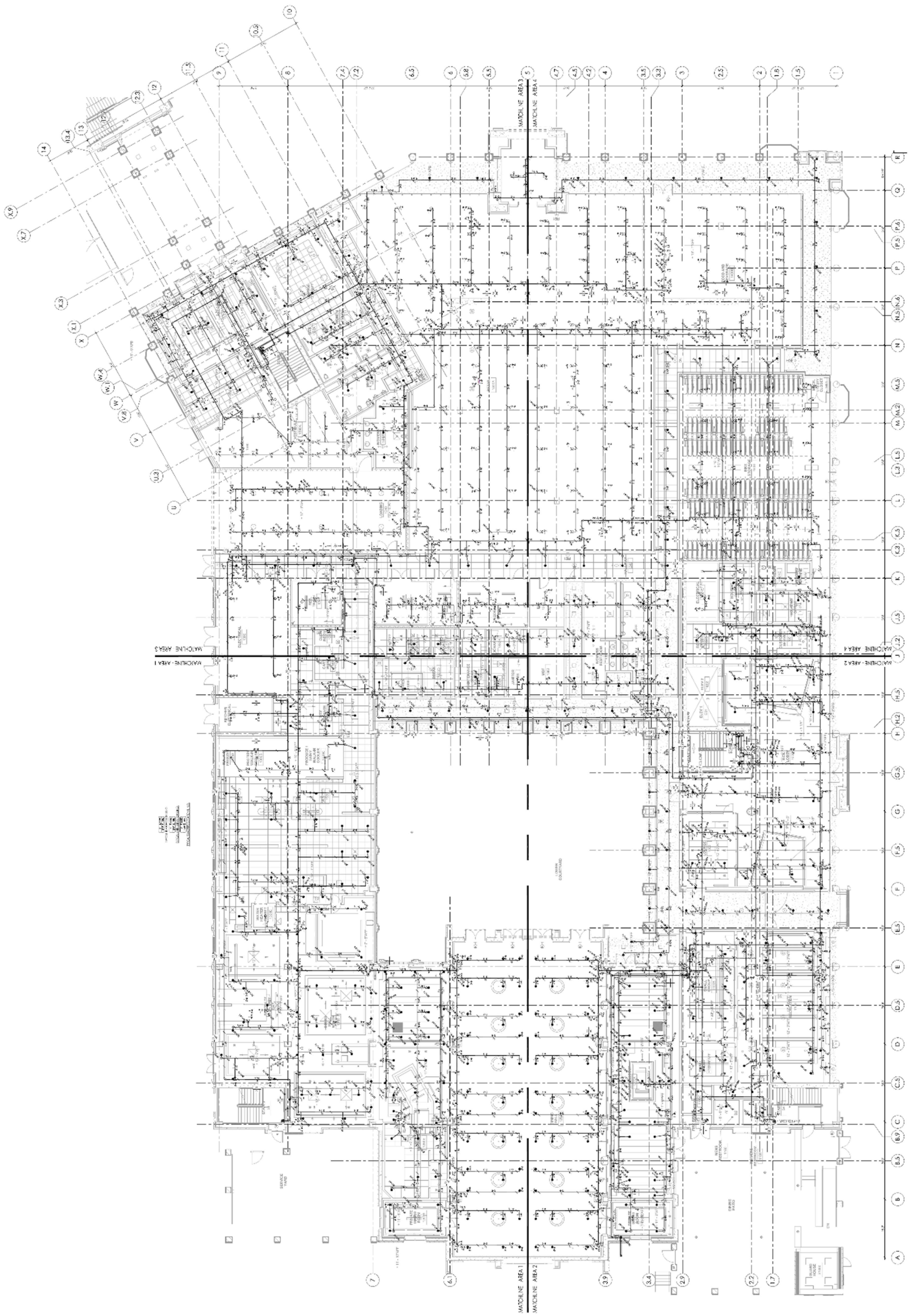

LEVEL 2 - FIRE ALARM LAYOUT
SCALE: 3/32"=1'-0"
NORTH


NORTH
LEVEL 3 - FIRE ALARM LAYOUT
SCALE: 3/32"=1'-0"

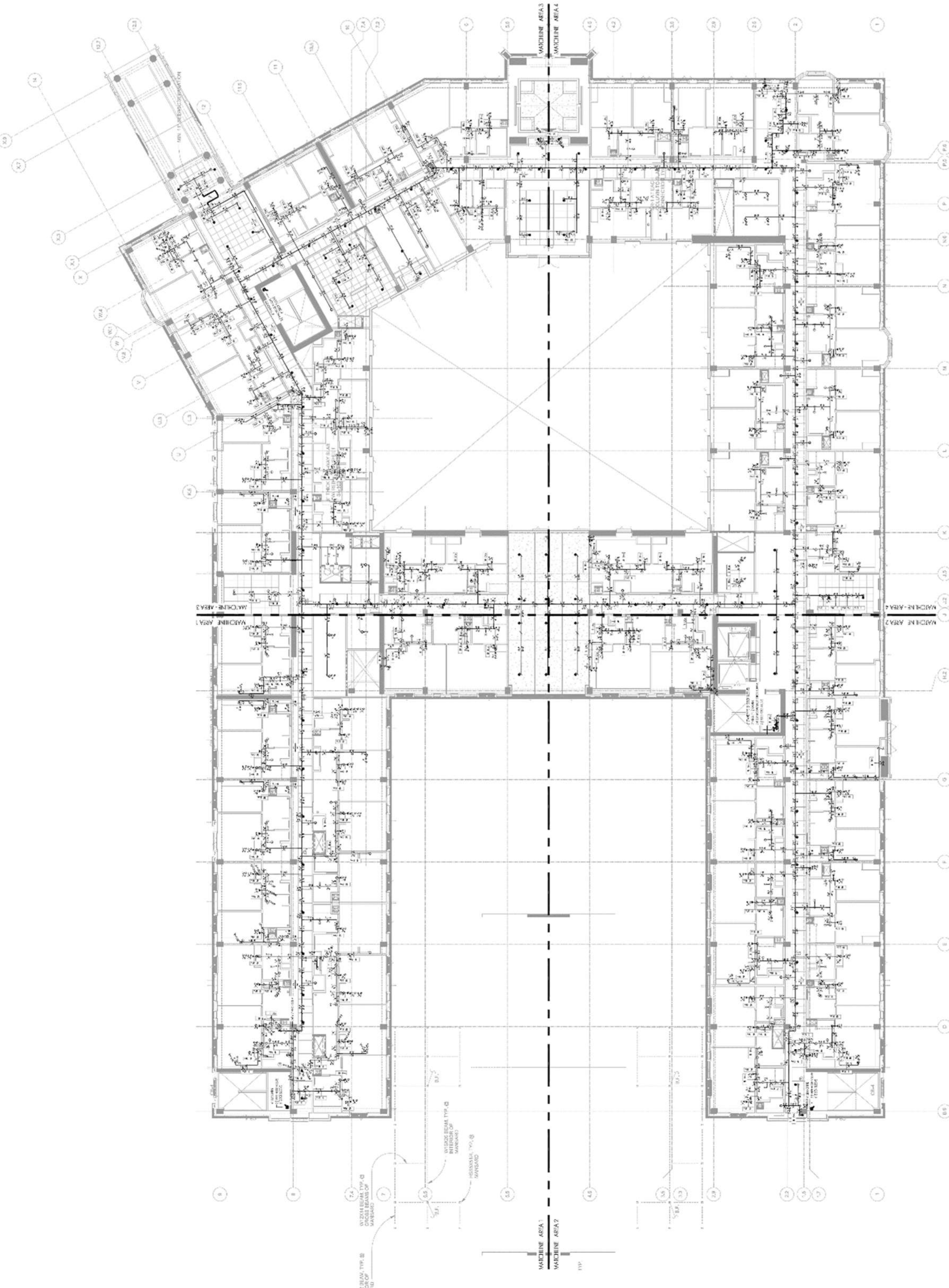

LEVEL 4 - FIRE ALARM LAYOUT
SCALE: 3/32"=1'-0"
NORTH


LEVEL 5 - FIRE ALARM LAYOUT
SCALE: 3/32"=1'-0"
NORTH

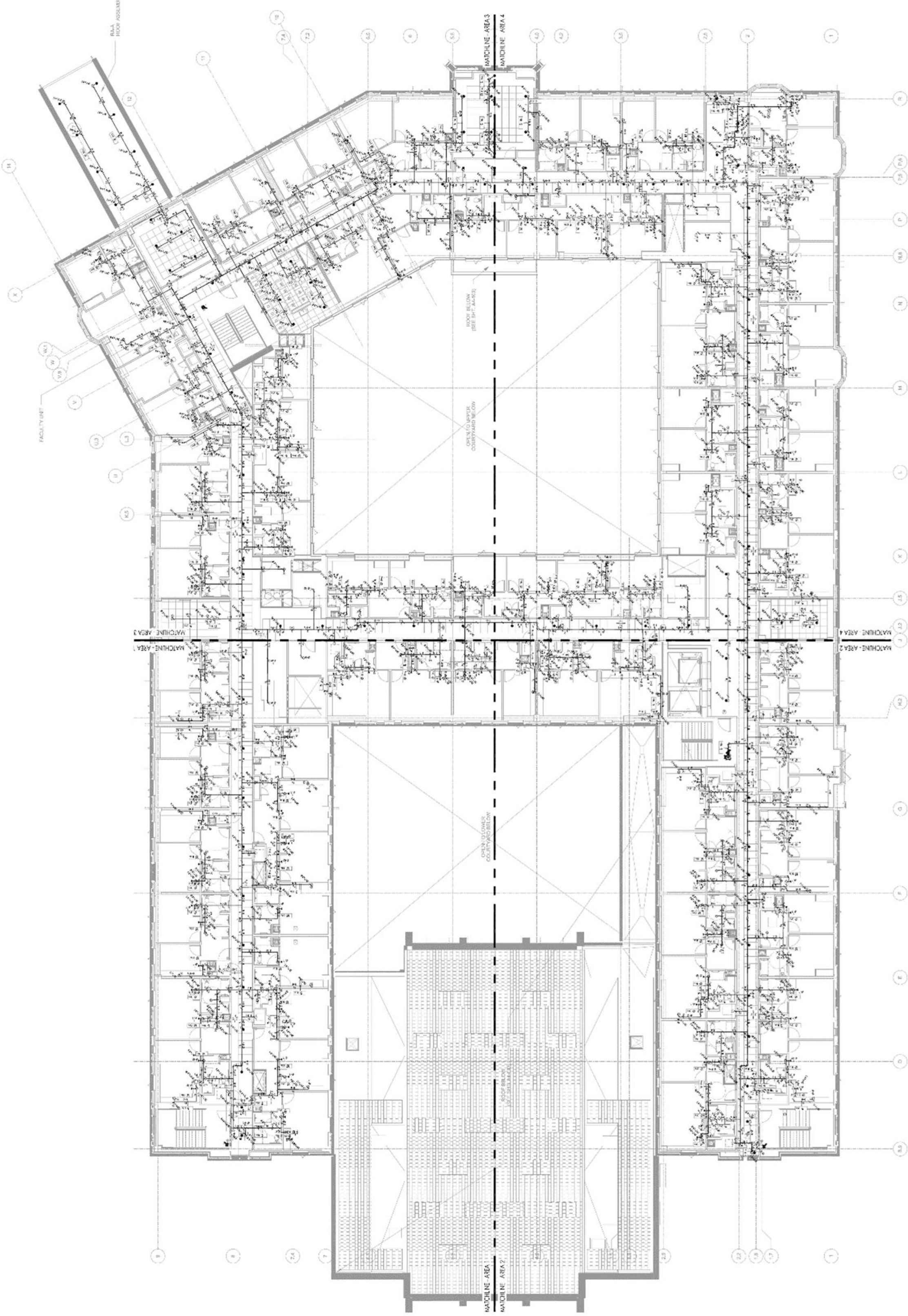
Appendix B – Fire Sprinkler Drawings



LEVEL 1 FIRE SPRINKLER PIPING PLAN - OVERALL
3/32" = 1'-0"

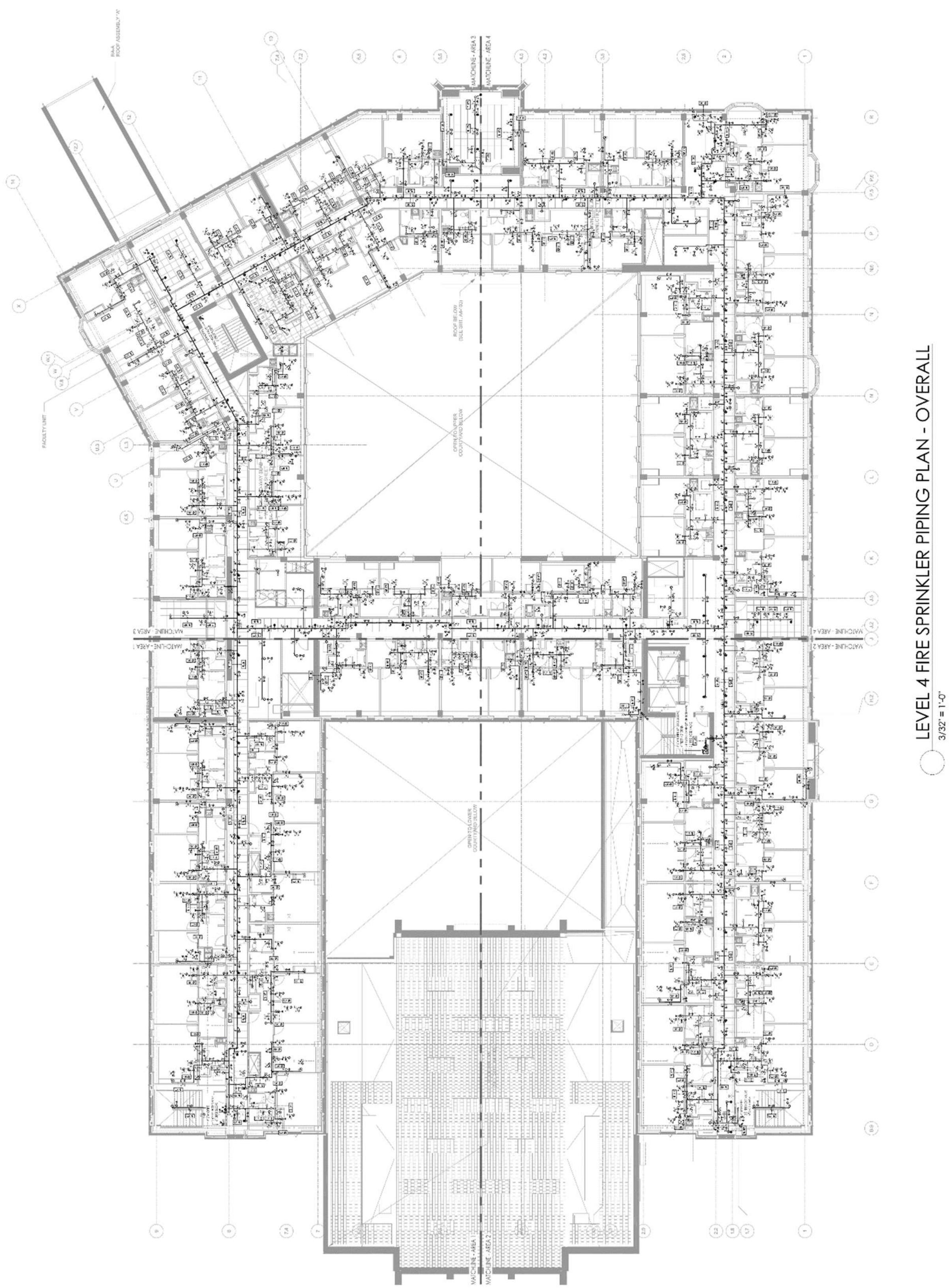


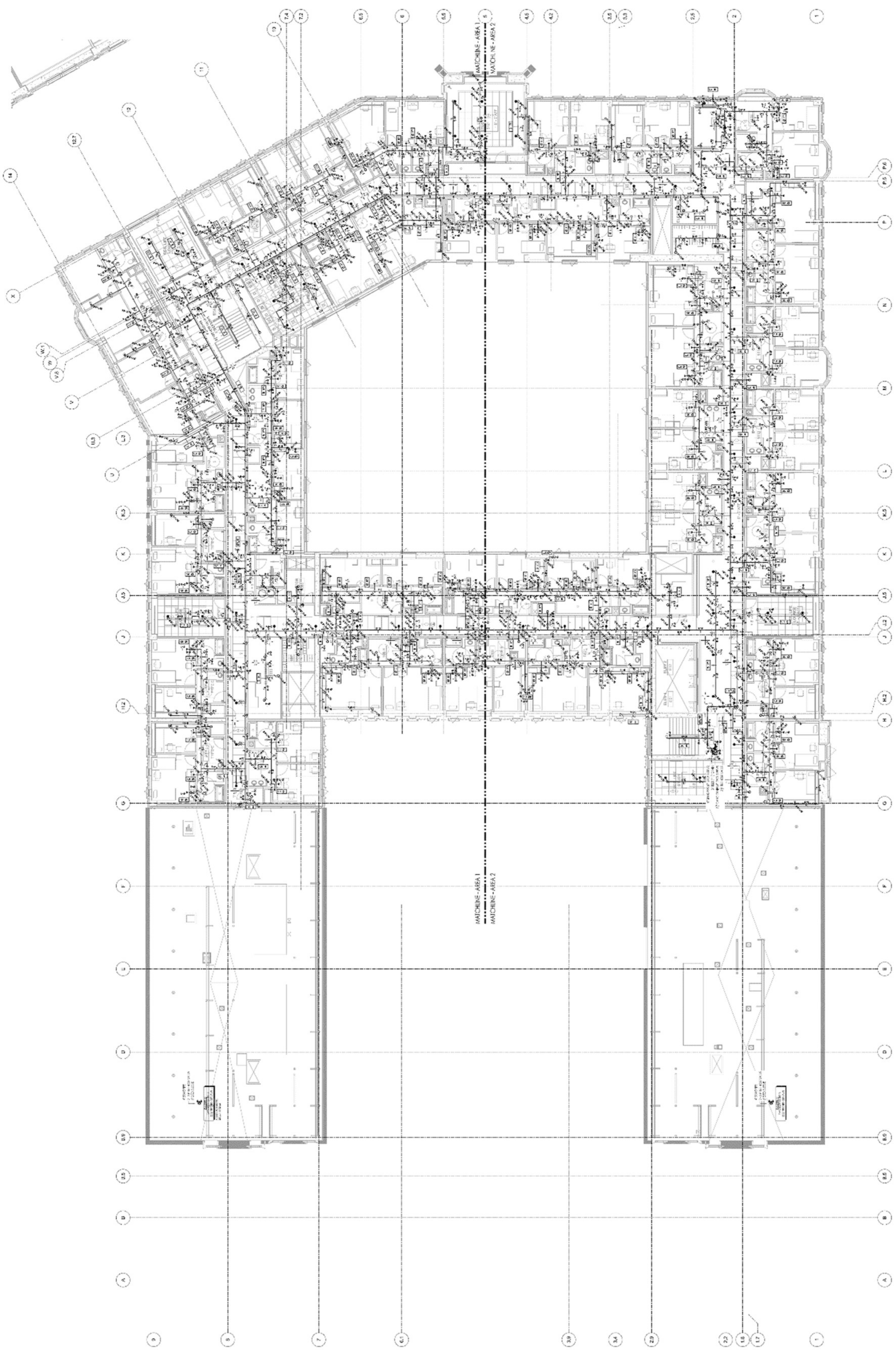
LEVEL 2 FIRE SPRINKLER PIPING PLAN - OVERALL
3/32" = 1'-0"



LEVEL 3 FIRE SPRINKLER PIPING PLAN - OVERALL

3/32" = 1'-0"

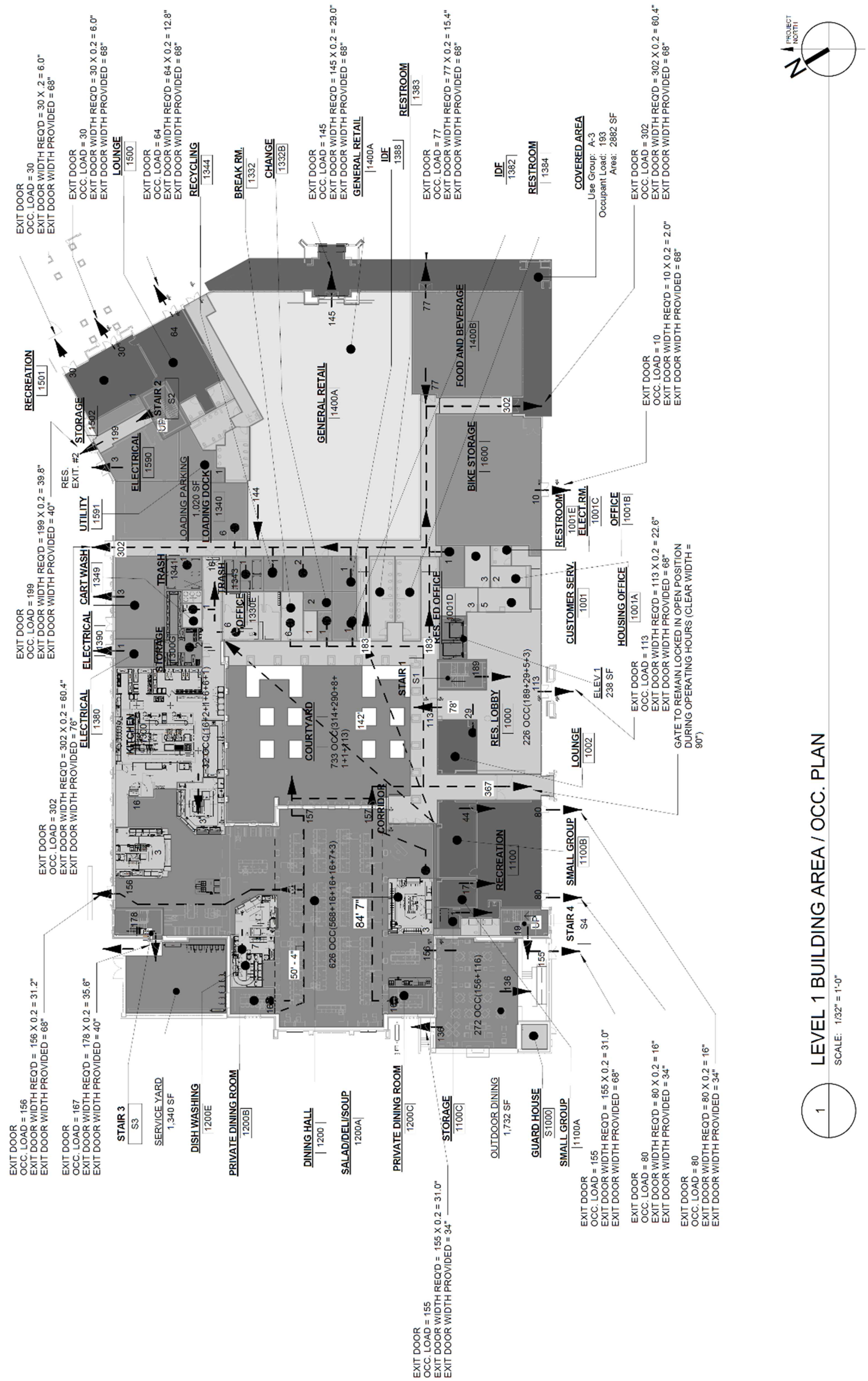

LEVEL 4 FIRE SPRINKLER PIPING PLAN - OVERALL
3/32" = 1'-0"



LEVEL 5 - OVERALL PIPING PLAN

3/32" = 1'-0"

Appendix C – Occupant Loads per Floor



AREA SCHEDULE (LEVEL 1)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
	COVERED AREA	A-3	2,882 SF	15	193
	CORRIDOR	B	2,948 SF	200	15
	CORRIDOR	R-2	177 SF	200	1
1000	RES. LOBBY	B	2,520 SF	100	26
1001	CUSTOMER SERV.	B	258 SF	100	3
1001A	HOUSING OFFICE	B	175 SF	100	2
1001B	OFFICE	B	216 SF	100	3
1001C	ELECT.RM.	S-2	207 SF	300	1
1001D	RES. ED OFFICE	B	211 SF	100	3
1001E	RESTROOM	B	85 SF	200	1
1002	LOUNGE	B	427 SF	15	29
1100	RECREATION	A-3	1,459 SF	15	98
1100A	SMALL GROUP	A-3	245 SF	15	17
1100B	SMALL GROUP	A-3	653 SF	15	44
1100C	STORAGE	S-2	111 SF	300	1
1180	RESTROOM	B	70 SF	200	1
1181	RESTROOM	B	70 SF	200	1
1183	FIRE RISER2	S-2	40 SF	200	1
1200	DINING HALL	A-2	8,513 SF	15	568
1200A	SALAD/DELI/SOUP	B	510 SF	200	17
1200B	PRIVATE DINING ROOM	A-2	227 SF	15	16
1200C	PRIVATE DINING ROOM	A-2	234 SF	15	16
1200E	DISH WASHING	B	700 SF	100	7
1250	SALAD/DELI/SOUP	B	552 SF	200	3
1250	VEGAN	B	485 SF	200	3
1300	KITCHEN	B	3,141 SF	200	16
1300G	STORAGE	S-2	475 SF	300	2
1330E	OFFICE	B	582 SF	100	6
1332	BREAK RM.	B	221 SF	15	3
1332A	CHANGE	S-2	86 SF	100	1
1332B	CHANGE	S-2	113 SF	100	2
1340	LOADING DOCK	S-2	510 SF	300	2
1340	LOADING PARKING	S-2	1,020 SF	300	4
1341	TRASH	S-2	253 SF	300	1
1342	CHEM ROOM	B	54 SF	100	1

LEVEL 1 AREA SUMMARY:

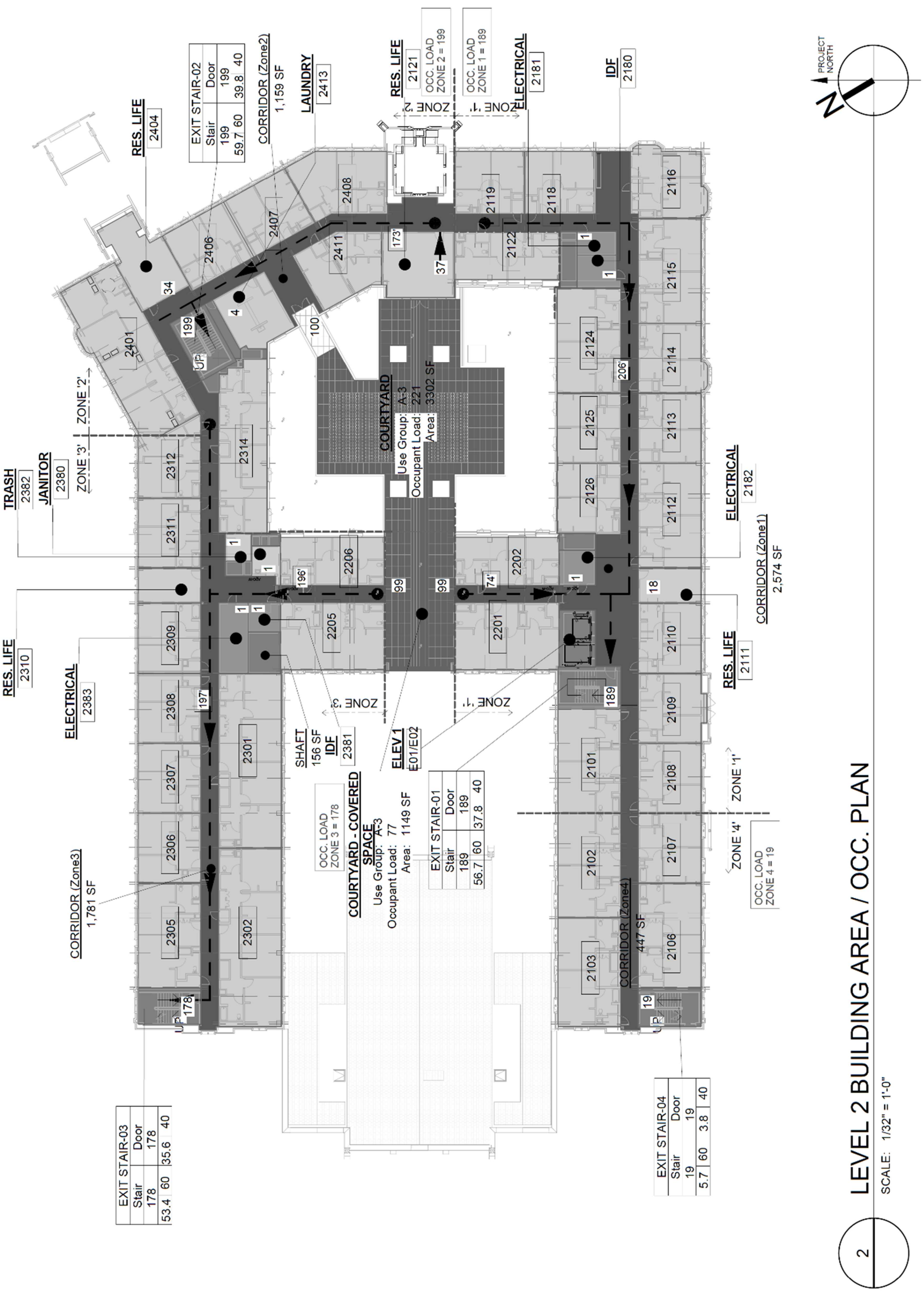
FLOOR AREA = **62,472 S.F.**
(NOT INCLUDING SURROUNDING EXTERIOR WALLS)

STAIRS AREA =	-	1,153 S.F.
ELEVATOR SHAFT AREA =	-	238 S.F.
COURTYARD =	-	4,346 S.F.
GUARD HOUSE =	-	127 S.F.
SERVICE YARD =	-	1,340 S.F.
OUTDOOR DINING =	-	1,732 S.F

ADJUSTED BUILDING AREA = **53,536 S.F.**
(SECTION 501.2 DEFINITION)

BIKE PARKING	-	2,752 S.F.
ELEC./SERVICE CLOSETS	-	3,833 S.F.

AREA SCHEDULE (LEVEL 1)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
1343	TRASH	S-2	288 SF	300	1
1344	RECYCLING	S-2	136 SF	300	1
1345	STORAGE	S-2	345 SF	300	2
1348	HALLWAY	B	1,933 SF	200	10
1349	CART WASH	B	98 SF	100	1
1380	ELECTRICAL	S-2	212 SF	300	1
1381	JANITOR	S-2	90 SF	200	1
1382	IDF	S-2	244 SF	300	1
1383	RESTROOM	B	407 SF	200	2
1384	RESTROOM	B	412 SF	200	3
1388	IDF	S-2	172 SF	300	1
1390	ELECTRICAL	S-2	811 SF	300	3
1400A	GENERAL RETAIL	M	8,667 SF	30	289
1400B	FOOD AND BEVERAGE	A-2	2,298 SF	15	154
1480	HALLWAY	B	485 SF	200	
1481	RESTROOM	B	305 SF	200	2
1482	RESTROOM	B	286 SF	200	2
1500	LOUNGE	A-3	949 SF	15	64
1500A	RESTROOM	B	77 SF	200	1
1500B	RESTROOM	B	89 SF	200	1
1501	RECREATION	A-3	880 SF	15	59
1502	STORAGE	S-2	168 SF	300	1
1590	ELECTRICAL	S-2	669 SF	300	3
1591	UTILITY	S-2	335 SF	300	1
1600	BIKE STORAGE	S-2	2,752 SF	300	10
60			53,536 SF		1722


LEVEL 2 BUILDING AREA / OCC. PLAN
SCALE: 1/32" = 1'-0"
2
PROJECT NORTH
N
COURTYARD
Use Group: A-3
Occupant Load: 221
Area: 3302 SF
COURTYARD - COVERED SPACE
Use Group: A-3
Occupant Load: 77
Area: 1149 SF
OCC. LOAD ZONE 2 = 199
OCC. LOAD ZONE 1 = 189
OCC. LOAD ZONE 3 = 178
OCC. LOAD ZONE 4 = 19
ZONE '1'
ZONE '2'
ZONE '3'
ZONE '4'
EXIT STAIR-01
Stair Door
189 189
56.7 60 37.8 40
EXIT STAIR-02
Stair Door
199 199
59.7 60 39.8 40
EXIT STAIR-03
Stair Door
178 178
53.4 60 35.6 40
EXIT STAIR-04
Stair Door
19 19
5.7 60 3.8 40
CORRIDOR (Zone1) 2,574 SF
CORRIDOR (Zone2) 1,159 SF
CORRIDOR (Zone3) 1,781 SF
CORRIDOR (Zone4) 447 SF
RES. LIFE 2404
RES. LIFE 2121
RES. LIFE 2310
RES. LIFE 2111
LAUNDRY 2413
ELECTRICAL 2181
ELECTRICAL 2182
ELECTRICAL 2383
IDF 2180
IDF 2381
TRASH 2382
JANITOR 2380
SHAFT 156 SF
ELEV 1 E01/E02
2101 2102 2103 2106 2107 2108 2109 2110 2112 2113 2114 2115 2116 2118 2119 2122 2124 2125 2126
2201 2202 2205 2206
2301 2302 2305 2306 2307 2308 2309 2311 2312 2314
2401 2406 2407 2408 2411

AREA SCHEDULE (LEVEL 2, ZONE 3)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2380	JANITOR	B	106 SF	100	1
2382	TRASH	B	87 SF	100	1
2205 - Type H	RES. UNITS	R-2	820 SF	200	5
2206 - Type F	RES. UNITS	R-2	589 SF	200	3
2301 - Type M3	RES. UNITS	R-2	1,291 SF	200	7
2302 - Type M2	RES. UNITS	R-2	1,317 SF	200	7
2305 - Type H	RES. UNITS	R-2	775 SF	200	4
2306 - Type E	RES. UNITS	R-2	516 SF	200	3
2307 - Type E	RES. UNITS	R-2	516 SF	200	3
2308 - Type E	RES. UNITS	R-2	516 SF	200	3
2309 - Type E	RES. UNITS	R-2	517 SF	200	3
2310	RES. LIFE	R-2	258 SF	15	18
2311 - Type E	RES. UNITS	R-2	516 SF	200	3
2312 - Type E1	RES. UNITS	R-2	515 SF	200	3
2314 - Type L1	RES. UNITS	R-2	965 SF	200	5
CORRIDOR (Zone3)	CORRIDOR (Zone3)	R-2	1,781 SF	200	8
2381	IDF	S-2	111 SF	300	1
2383	ELECTRICAL	S-2	244 SF	300	1
18			11,442 SF		79

LEVEL 2 SUMMARY:

TOTAL FLOOR AREA = **41,100** S.F.

OCC. LOAD - ZONE 1 = 189
OCC. LOAD - ZONE 2 = 199
OCC. LOAD - ZONE 3 = 178
OCC. LOAD - ZONE 4 = 19

TOTAL OCCUPANT LOAD = 585

NO. OF EXIT REQUIRED = 3
NO. OF EXIT PROVIDED = 4

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 1
=189 X 0.2 = 37.8" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 2
= 199 X 0.2 = 39.8" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 3
= 178 X 0.2 = 35.6" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 4
= 19 X 0.2 = 3.8" (PROVIDED = 40")

MIN. WIDTH PROVIDED @ CORRIDOR = 53"

LEVEL 2 AREA SUMMARY:

FLOOR AREA = 41,100 S.F.
(NOT INCLUDING SURROUNDING EXTERIOR WALLS)
COURTYARD = - 3,302 S.F.
STAIRS AREA = - 1,173 S.F.
ELEVATOR SHAFT AREA = - 242 S.F.
MECHANICAL SHAFT AREA = - 581 S.F.

ADJUSTED BUILDING AREA = 35,802 S.F.
(SECTION 501.2 DEFINITION)

ELEC./DATA/SERVICE CLOSETS = - 771 S.F.

AREA SCHEDULE (LEVEL 2, ZONE 1)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
	CORRIDOR (Zone1)	R-2	2,574 SF	200	12
2101 - Type H	RES. UNITS	R-2	772 SF	200	4
2108 - Type E	RES. UNITS	R-2	516 SF	200	3
2109 - Type E	RES. UNITS	R-2	536 SF	200	3
2110 - Type E_ACC	RES. UNITS	R-2	516 SF	200	3
2111	RES. LIFE	R-2	258 SF	15	18
2112 - Type H_ACC	RES. UNITS	R-2	775 SF	200	4
2114 - Type C	RES. UNITS	R-2	517 SF	200	3
2114 - Type C	RES. UNITS	R-2	536 SF	200	3
2115 - Type H	RES. UNITS	R-2	775 SF	200	4
2116 - Type E3	RES. UNITS	R-2	594 SF	200	3
2118 - Type E	RES. UNITS	R-2	524 SF	200	3
2119 - Type C	RES. UNITS	R-2	518 SF	200	3
2122 - Type F	RES. UNITS	R-2	594 SF	200	3
2124 - Type H	RES. UNITS	R-2	788 SF	200	4
2125 - Type C	RES. UNITS	R-2	524 SF	200	3
2126 - Type C	RES. UNITS	R-2	527 SF	200	3
2201 - Type H	RES. UNITS	R-2	820 SF	200	5
2202 - Type F	RES. UNITS	R-2	591 SF	200	3
2180	IDF	S-2	158 SF	300	1
2181	ELECTRICAL	S-2	109 SF	300	1
2182	ELECTRICAL	S-2	150 SF	300	1
22			13,671 SF		90

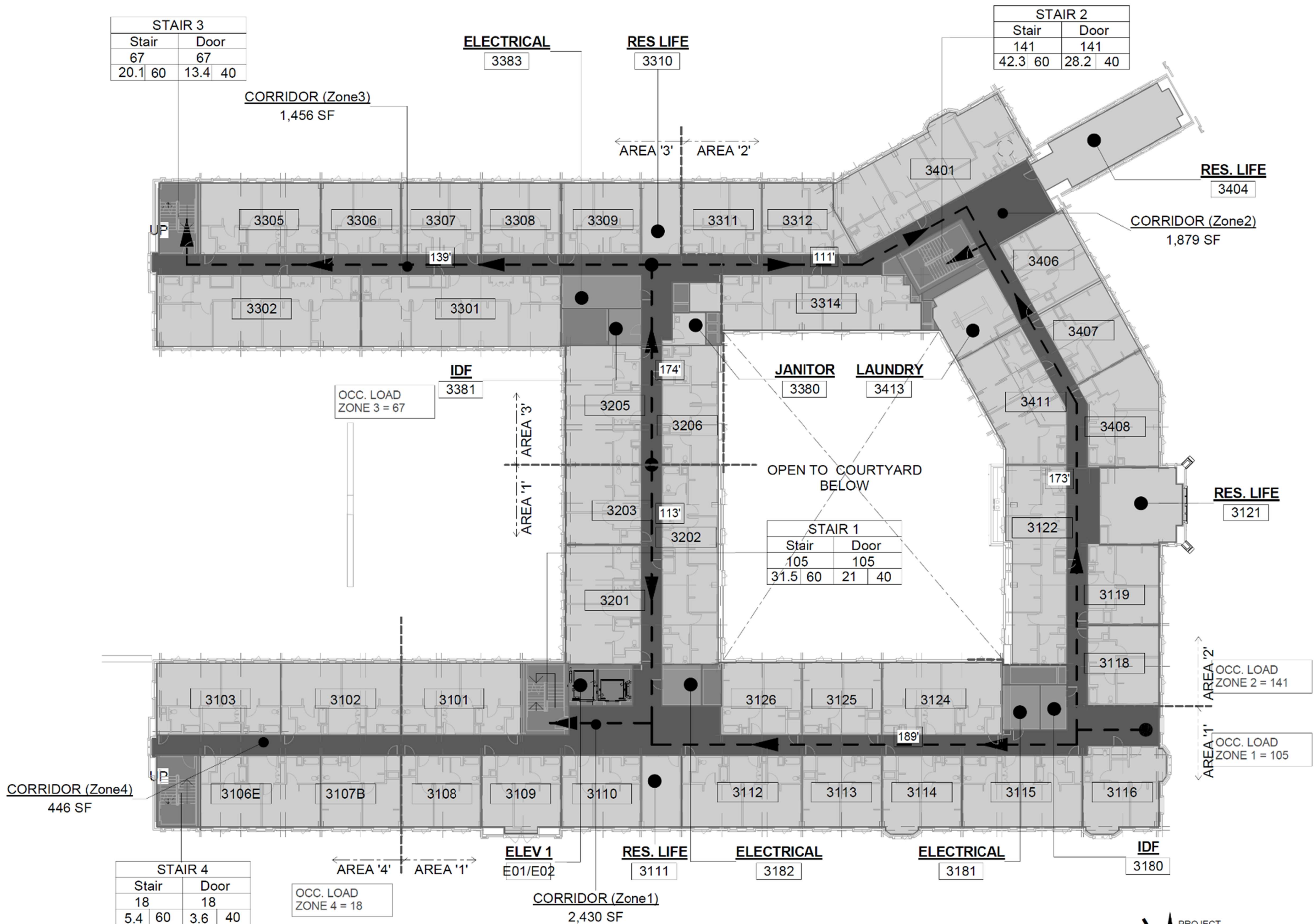
AREA SCHEDULE (LEVEL 2, ZONE 2)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2413	LAUNDRY	B	440 SF	100	4
2121	RES. LIFE	R-2	558 SF	15	37
2401 - Type M1	RES. UNITS	R-2	1,285 SF	200	6
2404	RES. LIFE	R-2	515 SF	15	34
2406 - Type E	RES. UNITS	R-2	517 SF	200	3
2407 - Type C	RES. UNITS	R-2	516 SF	200	3
2408 - Type H3	RES. UNITS	R-2	667 SF	200	3
2411 - Type E2	RES. UNITS	R-2	569 SF	200	3
CORRIDOR (Zone2)	CORRIDOR (Zone2)	R-2	1,159 SF	200	6
9			6,227 SF		99

AREA SCHEDULE (LEVEL 2, ZONE 4)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
2102 - Type H	RES. UNITS	R-2	775 SF	200	4
2103 - Type H	RES. UNITS	R-2	800 SF	200	5
2106 - Type C	RES. UNITS	R-2	775 SF	200	4
2107 - Type H	RES. UNITS	R-2	516 SF	200	3
CORRIDOR (Zone4)	CORRIDOR (Zone4)	R-2	447 SF	200	3
5			3,313 SF		19

COURTYARD - COVERED SPACE / A-3 / 1,149 SF / 15 / 77



3 LEVEL 3 BUILDING AREA / OCC. PLAN

SCALE: 1/32" = 1'-0"

AREA SCHEDULE (LEVEL 3, ZONE 3)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
	SHAFT	(none)	87 SF	300	0
3380	JANITOR	B	105 SF	100	1
3205 - Type H	RES. UNITS	R-2	820 SF	200	5
3206 - Type F	RES. UNITS	R-2	604 SF	200	3
3301 - Type M3	RES. UNITS	R-2	1,291 SF	200	7
3302 - Type M2	RES. UNITS	R-2	1,317 SF	200	7
3305 - Type H	RES. UNITS	R-2	775 SF	200	4
3306 - Type E	RES. UNITS	R-2	516 SF	200	3
3307 - Type E	RES. UNITS	R-2	516 SF	200	3
3308 - Type E	RES. UNITS	R-2	516 SF	200	3
3309 - Type E	RES. UNITS	R-2	517 SF	200	3
3310	RES LIFE	R-2	258 SF	15	18
CORRIDOR (Zone3)	CORRIDOR (Zone3)	R-2	1,456 SF	200	8
3381	IDF	S-2	111 SF	300	1
3383	ELECTRICAL	S-2	244 SF	300	1
15			9,133 SF		67

LEVEL 3 SUMMARY:

TOTAL FLOOR AREA = 38,713 S.F.
OCC. LOAD - ZONE 1 = 105
OCC. LOAD - ZONE 2 = 141
OCC. LOAD - ZONE 3 = 67
OCC. LOAD - ZONE 4 = 18
TOTAL OCCUPANT LOAD = 331
NO. OF EXIT REQUIRED = 2
NO. OF EXIT PROVIDED = 4
EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 1 = 105 X 0.2 = 21.0" (PROVIDED = 40")
EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 2 = 141 X 0.2 = 28.2" (PROVIDED = 40")
EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 3 = 67 X 0.2 = 13.4" (PROVIDED = 40")
EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 4 = 18 X 0.2 = 3.6" (PROVIDED = 40")
MIN. WIDTH PROVIDED @ CORRIDOR = 53"

LEVEL 3 AREA SUMMARY:

FLOOR AREA = 38,713 S.F.
(NOT INCLUDING SURROUNDING EXTERIOR WALLS)

STAIRS AREA = - 1,175 S.F.
ELEVATOR SHAFT AREA = - 242 S.F.
MECHANICAL SHAFT AREA = - 587 S.F.

ADJUSTED BUILDING AREA = 36,709 S.F.
(SECTION 501.2 DEFINITION)

ELEC./DATA/SERVICE CLOSETS = - 767 S.F.

AREA SCHEDULE (LEVEL 3, ZONE 1)

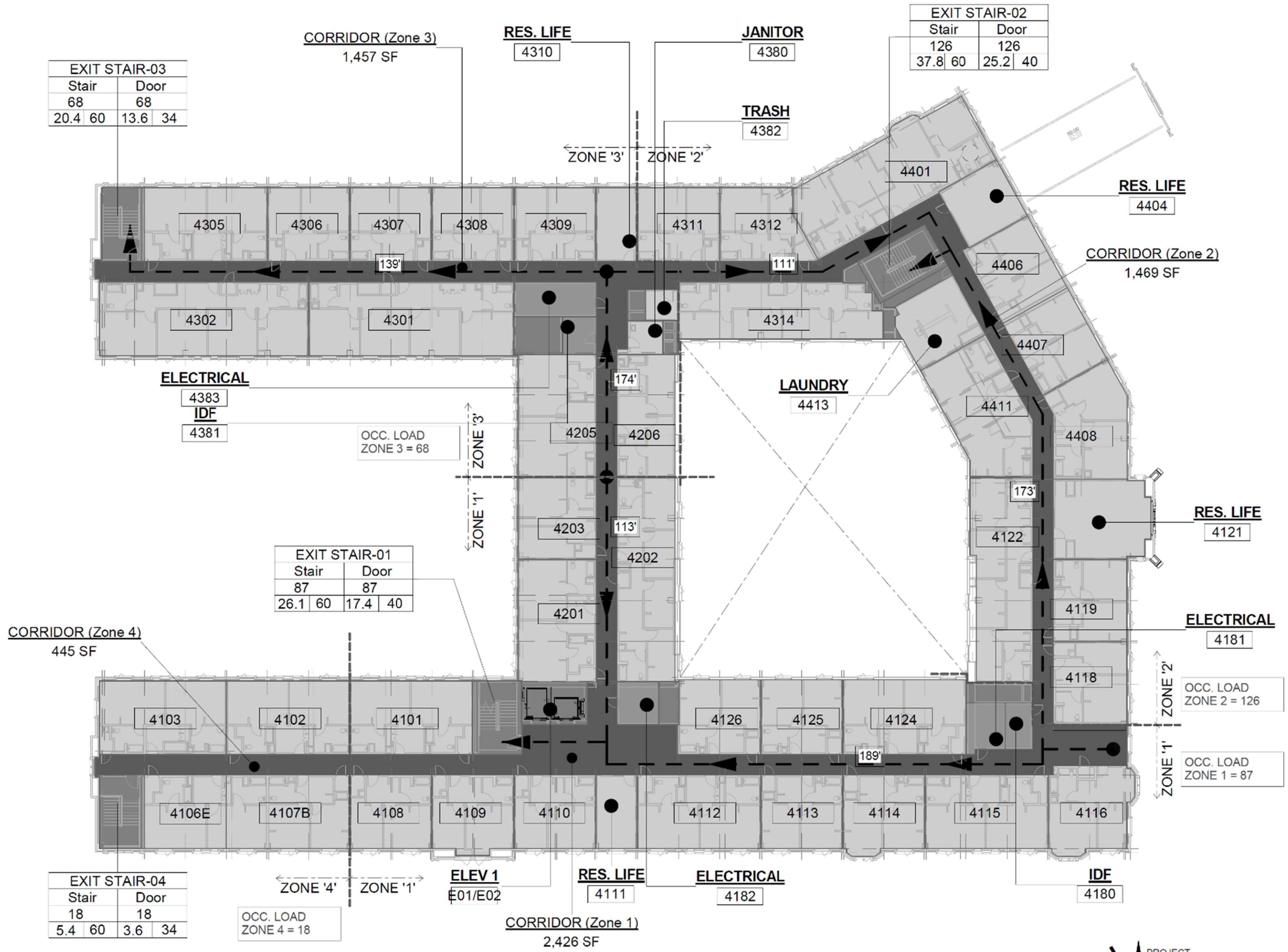
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
3101 - Type H	RES. UNITS	R-2	772 SF	200	4
3108 - Type E	RES. UNITS	R-2	516 SF	200	3
3109 - Type E	RES. UNITS	R-2	536 SF	200	3
3110 - Type E	RES. UNITS	R-2	516 SF	200	3
3111	RES. LIFE	R-2	258 SF	15	18
3112 - Type H	RES. UNITS	R-2	775 SF	200	4
3113 - Type C	RES. UNITS	R-2	517 SF	200	3
3114 - Type C	RES. UNITS	R-2	536 SF	200	3
3115 - Type H	RES. UNITS	R-2	775 SF	200	4
3116 - Type E3	RES. UNITS	R-2	594 SF	200	3
3124 - Type H	RES. UNITS	R-2	788 SF	200	4
3125 - Type C	RES. UNITS	R-2	524 SF	200	3
3126 - Type C	RES. UNITS	R-2	527 SF	200	3
3201 - Type H	RES. UNITS	R-2	820 SF	200	5
3202 - Type L	RES. UNITS	R-2	1,008 SF	200	5
3203 - Type E	RES. UNITS	R-2	550 SF	200	3
CORRIDOR (Zone1)	CORRIDOR (Zone1)	R-2	2,430 SF	200	31
3180	IDF	S-2	109 SF	300	1
3181	ELECTRICAL	S-2	154 SF	300	1
3182	ELECTRICAL	S-2	150 SF	300	1
20			12,854 SF		105

AREA SCHEDULE (LEVEL 3, ZONE 2)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
3413	LAUNDRY	B	429 SF	100	5
3118 - Type E	RES. UNITS	R-2	524 SF	200	3
3119 - Type C	RES. UNITS	R-2	518 SF	200	3
3121	RES. LIFE	R-2	554 SF	15	37
3122 - Type L	RES. UNITS	R-2	1,029 SF	200	6
3311 - Type E	RES. UNITS	R-2	516 SF	200	3
3312 - Type E1	RES. UNITS	R-2	515 SF	200	3
3314 - Type L1	RES. UNITS	R-2	966 SF	200	5
3401 - Type M1	RES. UNITS	R-2	1,291 SF	200	7
3404	RES. LIFE	R-2	652 SF	15	44
3406 - Type E	RES. UNITS	R-2	517 SF	200	3
3407 - Type C	RES. UNITS	R-2	516 SF	200	3
3408 - Type H3	RES. UNITS	R-2	667 SF	200	4
3411 - Type H2	RES. UNITS	R-2	835 SF	200	5
CORRIDOR (Zone2)	CORRIDOR (Zone2)	R-2	1,879 SF	200	10
15			11,409 SF		141

AREA SCHEDULE (LEVEL 3, ZONE 4)

Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
3102 - Type H	RES. UNITS	R-2	775 SF	200	4
3103 - Type H1	RES. UNITS	R-2	800 SF	200	4
3106 - Type C	RES. UNITS	R-2	776 SF	200	4
3107 - Type H	RES. UNITS	R-2	516 SF	200	3
CORRIDOR (Zone4)	CORRIDOR (Zone4)	R-2	446 SF	200	3
5			3,313 SF		18



4 LEVEL 4 BUILDING AREA / OCC. PLAN

SCALE: 1/32" = 1'-0"

AREA SCHEDULE (LEVEL 4, ZONE 3)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
4380	JANITOR	B	107 SF	100	1
4382	TRASH	B	87 SF	100	1
4205 - Type H	RES. UNITS	R-2	820 SF	200	5
4206 - Type F	RES. UNITS	R-2	604 SF	200	3
4301 - Type M3	RES. UNITS	R-2	1,291 SF	200	7
4302 - Type M2	RES. UNITS	R-2	1,317 SF	200	7
4305 - Type H	RES. UNITS	R-2	775 SF	200	4
4306 - Type E	RES. UNITS	R-2	516 SF	200	3
4307 - Type E	RES. UNITS	R-2	516 SF	200	3
4308 - Type E	RES. UNITS	R-2	516 SF	200	3
4309 - Type E	RES. UNITS	R-2	517 SF	200	3
4310	RES. LIFE	R-2	258 SF	15	18
CORRIDOR (Zone 3)	CORRIDOR (Zone 3)	R-2	1,457 SF	200	8
4381	IDF	S-2	111 SF	300	1
4383	ELECTRICAL	S-2	244 SF	300	1
15			9,136 SF		68

LEVEL 4 SUMMARY:

TOTAL FLOOR AREA = **38,089** S.F.

OCC. LOAD - ZONE 1 = 87
OCC. LOAD - ZONE 2 = 126
OCC. LOAD - ZONE 3 = 68
OCC. LOAD - ZONE 4 = 18

TOTAL OCCUPANT LOAD = 299

NO. OF EXIT REQUIRED = 2
NO. OF EXIT PROVIDED = 4

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 1 = 87 X 0.2 = 17.4" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 2 = 126 X 0.2 = 25.2" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 3 = 68 X 0.2 = 13.6" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 4 = 18 X 0.2 = 3.6" (PROVIDED = 40")

MIN. WIDTH PROVIDED @ CORRIDOR = 53"

LEVEL 4 AREA SUMMARY:

FLOOR AREA = 38,089 S.F.
(NOT INCLUDING SURROUNDING EXTERIOR WALLS)

STAIRS AREA = - 1,175 S.F.
ELEVATOR SHAFT AREA = - 242 S.F.
MECHANICAL SHAFT AREA = - 585 S.F.

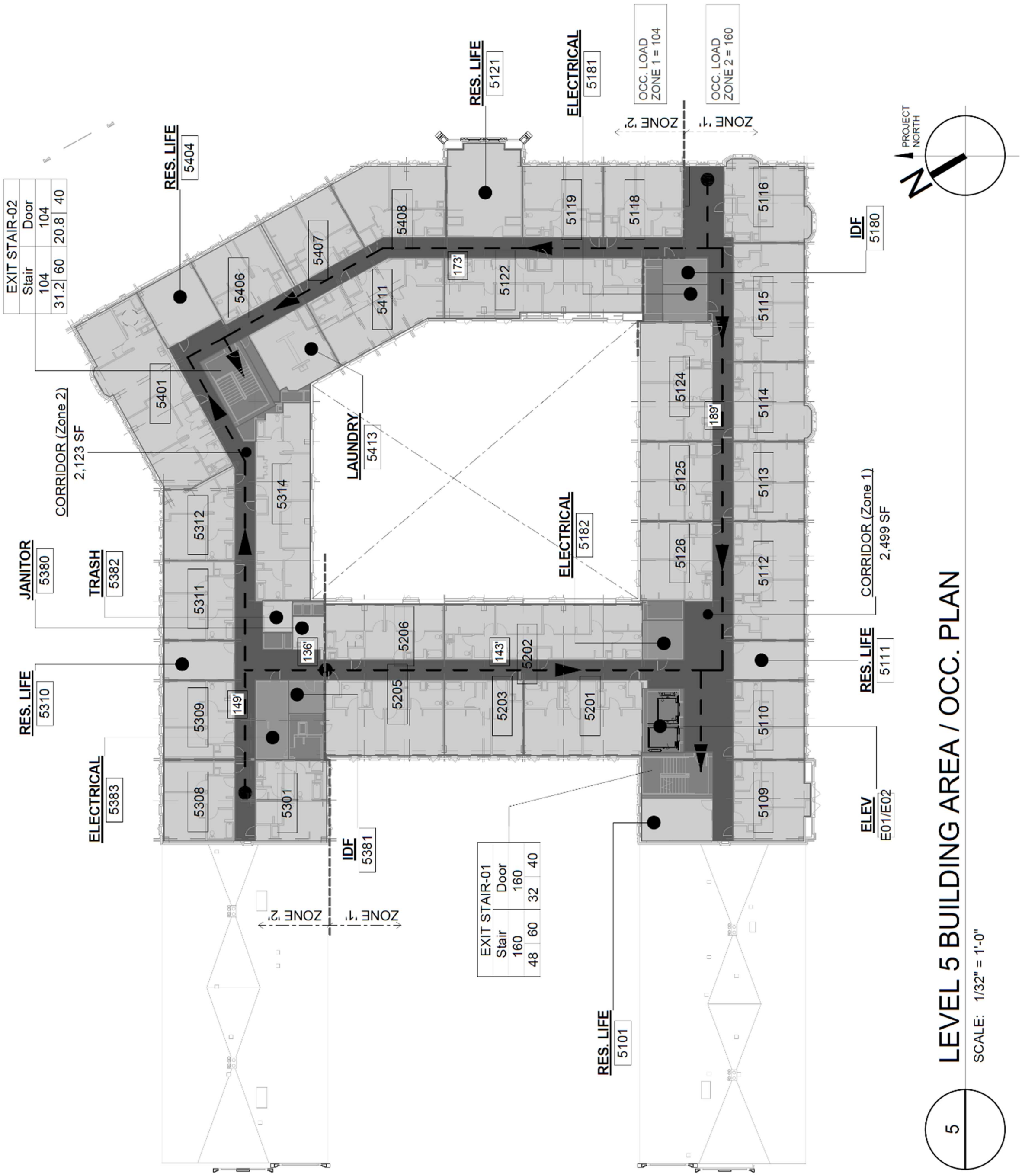
ADJUSTED BUILDING AREA = 36,087 S.F.
(SECTION 501.2 DEFINITION)

ELEC./DATA/SERVICE CLOSETS = - 774 S.F.

AREA SCHEDULE (LEVEL 4, ZONE 1)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
4101 - Type H	RES. UNITS	R-2	772 SF	200	4
4108 - Type E	RES. UNITS	R-2	516 SF	200	3
4109 - Type E	RES. UNITS	R-2	536 SF	200	3
4110 - Type E	RES. UNITS	R-2	516 SF	200	3
4111	RES. LIFE	R-2	258 SF	15	18
4112 - Type H	RES. UNITS	R-2	775 SF	200	4
4113 - Type C	RES. UNITS	R-2	516 SF	200	3
4114 - Type C	RES. UNITS	R-2	536 SF	200	3
4115 - Type H	RES. UNITS	R-2	775 SF	200	4
4116 - Type E3	RES. UNITS	R-2	594 SF	200	3
4124 - Type H	RES. UNITS	R-2	788 SF	200	4
4125 - Type C	RES. UNITS	R-2	524 SF	200	3
4126 - Type C	RES. UNITS	R-2	525 SF	200	3
4201 - Type H	RES. UNITS	R-2	820 SF	200	5
4202 - Type L	RES. UNITS	R-2	1,008 SF	200	5
4203 - Type E	RES. UNITS	R-2	550 SF	200	3
CORRIDOR (Zone 1)	CORRIDOR (Zone 1)	R-2	2,426 SF	200	13
4180	IDF	S-2	109 SF	300	1
4181	ELECTRICAL	S-2	158 SF	300	1
4182	ELECTRICAL	S-2	152 SF	300	1
20			12,855 SF		87

AREA SCHEDULE (LEVEL 4, ZONE 2)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
4413	LAUNDRY	B	429 SF	100	5
4118 - Type E	RES. UNITS	R-2	524 SF	200	3
4119 - Type C	RES. UNITS	R-2	516 SF	200	3
4121	RES. LIFE	R-2	639 SF	15	43
4122 - Type L	RES. UNITS	R-2	1,029 SF	200	6
4311 - Type E	RES. UNITS	R-2	516 SF	200	3
4312 - Type E1	RES. UNITS	R-2	515 SF	200	3
4314 - Type L1	RES. UNITS	R-2	965 SF	200	5
4401 - Type M1F	RES. UNITS	R-2	1,285 SF	200	7
4404	RES. LIFE	R-2	363 SF	15	25
4406 - Type E	RES. UNITS	R-2	518 SF	200	3
4407 - Type C	RES. UNITS	R-2	516 SF	200	3
4408 - Type H3	RES. UNITS	R-2	666 SF	200	4
4411 - Type H2	RES. UNITS	R-2	834 SF	200	5
CORRIDOR (Zone 2)	CORRIDOR (Zone 2)	R-2	1,469 SF	200	8
15			10,785 SF		126

AREA SCHEDULE (LEVEL 4, ZONE 4)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
4102 - Type H	RES. UNITS	R-2	775 SF	200	4
4103 - Type H1	RES. UNITS	R-2	800 SF	200	4
4106 - Type C	RES. UNITS	R-2	517 SF	200	3
4107 - Type H	RES. UNITS	R-2	775 SF	200	4
CORRIDOR (Zone 4)	CORRIDOR (Zone 4)	R-2	445 SF	200	3
5			3,311 SF		18



LEVEL 5 BUILDING AREA / OCC. PLAN

AREA SCHEDULE (LEVEL 5, ZONE 2)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
5380	JANITOR	B	104 SF	100	1
5382	TRASH	B	88 SF	100	1
5413	LAUNDRY	B	428 SF	100	5
5118 - Type E	RES. UNITS	R-2	524 SF	200	3
5119 - Type C	RES. UNITS	R-2	525 SF	200	3
5121	RES. LIFE	R-2	631 SF	15	43
5122 - Type L	RES. UNITS	R-2	1,029 SF	200	6
5301 - Type C	RES. UNITS	R-2	525 SF	200	3
5308 - Type E	RES. UNITS	R-2	525 SF	200	3
5309 - Type E	RES. UNITS	R-2	517 SF	200	3
5310	RES. LIFE	R-2	258 SF	15	18
5311 - Type E	RES. UNITS	R-2	516 SF	200	3
5312 - Type E1	RES. UNITS	R-2	515 SF	200	3
5314 - Type L1	RES. UNITS	R-2	965 SF	200	5
5401 - Type M1F	RES. UNITS	R-2	1,285 SF	200	7
5404	RES. LIFE	R-2	363 SF	15	25
5406 - Type E	RES. UNITS	R-2	517 SF	200	3
5407 - Type C	RES. UNITS	R-2	517 SF	200	3
5408 - Type H3	RES. UNITS	R-2	666 SF	200	4
5411 - Type H2	RES. UNITS	R-2	834 SF	200	5
CORRIDOR (Zone 2)	CORRIDOR (Zone 2)	R-2	2,123 SF	200	11
5381	IDF	S-2	113 SF	300	1
5383	ELECTRICAL	S-2	244 SF	300	1
23			13,812 SF		160

AREA SCHEDULE (LEVEL 5, ZONE 1)					
Unit Number & Type	Function	Occ.	Area	OLF	No. Occ.
5101	RES. LIFE	R-2	278 SF	15	19
5109 - Type E	RES. UNITS	R-2	545 SF	200	3
5110 - Type E	RES. UNITS	R-2	516 SF	200	3
5111	RES. LIFE	R-2	258 SF	15	18
5112 - Type H	RES. UNITS	R-2	775 SF	200	4
5113 - Type C	RES. UNITS	R-2	516 SF	200	3
5115 - Type H	RES. UNITS	R-2	775 SF	200	4
5116 - Type E3	RES. UNITS	R-2	594 SF	200	3
5124 - Type H	RES. UNITS	R-2	788 SF	200	4
5125 - Type C	RES. UNITS	R-2	524 SF	200	3
5126 - Type C	RES. UNITS	R-2	527 SF	200	3
5201 - Type H	RES. UNITS	R-2	824 SF	200	5
5202 - Type L	RES. UNITS	R-2	1,008 SF	200	6
5203 - Type E	RES. UNITS	R-2	550 SF	200	3
5205 - Type H	RES. UNITS	R-2	820 SF	200	5
5206 - Type F	RES. UNITS	R-2	604 SF	200	3
51145 - Type C	RES. UNITS	R-2	537 SF	200	3
CORRIDOR (Zone 1)	CORRIDOR (Zone 1)	R-2	2,499 SF	300	9
5180	IDF	S-2	109 SF	300	1
5181	ELECTRICAL	S-2	154 SF	300	1
5182	ELECTRICAL	S-2	150 SF	300	1
21			13,350 SF		104

LEVEL 5 SUMMARY:

TOTAL FLOOR AREA = 28,597 S.F.

OCC. LOAD - ZONE 1 = 104
OCC. LOAD - ZONE 2 = 160
TOTAL OCCUPANT LOAD = 264

NO. OF EXIT REQUIRED = 2
NO. OF EXIT PROVIDED = 2

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 1
= 104 X 0.2 = 20.8" (PROVIDED = 40")

EXIT DOOR WIDTH REQUIRED @ OCC. LOAD - ZONE 2
= 160 X 0.2 = 32.0" (PROVIDED = 40")

MIN. WIDTH PROVIDED @ CORRIDOR = 53"

LEVEL 5 AREA SUMMARY:

FLOOR AREA = 28,597 S.F.
(NOT INCLUDING SURROUNDING EXTERIOR WALLS)

STAIRS AREA = - 607 S.F.
ELEVATOR SHAFT AREA = - 242 S.F.
MECHANICAL SHAFT AREA = - 586 S.F.

ADJUSTED BUILDING AREA = 27,162 S.F.
(SECTION 501.2 DEFINITION)

ELEC./DATA/SERVICE CLOSETS = - 770 S.F.